Nos. 2023-1850, -2038

United States Court of Appeals
for the
Fourth Circuit

HONEYWELL INTERNATIONAL INC.; HAND HELD PRODUCTS, INC.; METROLOGIC INSTRUMENTS, INC.,

Plaintiffs-Appellants/Cross-Appellees,

v.

OPTO ELECTRONICS CO., LTD.,

Defendant-Appellee/Cross-Appellant.

On Appeal from the United States District Court for the Western District of North Carolina Case No. 3:21-cv-506-KDB-DCK

**JOINT APPENDIX
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April 1, 2024

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US009465970B2

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(12) **United States Patent**
Wang et al.

(10) **Patent No.: US 9,465,970 B2**
(45) **Date of Patent: *Oct. 11, 2016**

(54) **IMAGE READER COMPRISING CMOS BASED IMAGE SENSOR ARRAY**

(71) Applicant: **HAND HELD PRODUCTS, INC.**, Skaneateles Falls, NY (US)

(72) Inventors: **Ynjiun P. Wang**, Cupertino, CA (US); **William H. Havens**, Syracuse, NY (US)

(73) Assignee: **Hand Held Products, Inc.**, Skaneateles Falls, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/221,903**

(22) Filed: **Mar. 21, 2014**

(65) **Prior Publication Data**

US 2014/0204257 A1 Jul. 24, 2014

Related U.S. Application Data

(60) Continuation of application No. 13/052,768, filed on Mar. 21, 2011, now Pat. No. 8,733,660, which is a division of application No. 12/534,664, filed on Aug. 3, 2009, now Pat. No. 7,909,257, which is a division of application No. 11/077,975, filed on Mar. 11, 2005, now Pat. No. 7,568,628.

(51) **Int. Cl.**

G06K 7/14	(2006.01)
G06K 7/10	(2006.01)
H04N 5/374	(2011.01)

(52) **U.S. Cl.**
CPC ***G06K 7/1439*** (2013.01); ***G06K 7/10722*** (2013.01); ***H04N 5/374*** (2013.01)

(58) **Field of Classification Search**
CPC . H04N 5/374; G06K 7/1439; G06K 7/10722
See application file for complete search history.

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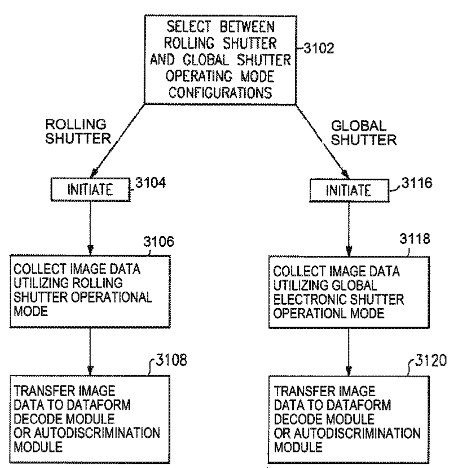
(57) **ABSTRACT**

The invention features an image reader and a corresponding method for capturing a sharp distortion free image of a target, such as a one or two-dimensional bar code. In one embodiment, the image reader comprises a two-dimensional CMOS based image sensor array, a timing module, an illumination module, and a control module. The time during which the target is illuminated is referred to as the illumination period. The capture of the image by the image sensor array is driven by the timing module that, in one embodiment, is able to simultaneously expose substantially all of the pixels in the array. The time during which the pixels are collectively activated to photo-convert incident light into charge defines the exposure period for the sensor array. In one embodiment, at least a portion of the exposure period occurs during the illumination period.

107 Claims, 30 Drawing Sheets



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Office Action for Chinease Application No. 201110220834.X dated Sep. 18, 2015.
Office Communication (Notice of Transmission of Documents) for Chinese Application No. 200680016023.5 dated Jun. 4, 2015.
Search Report for European Application No. 13 15 3147 dated Oct. 29, 2015.
Search Report for European Application No. 15 16 7739 dated Oct. 30, 2015.
Office Action for Japanese Application No. 2013-003616 datd May 19, 2014.
Appeal Decision for Japanese Application No. 2013-003616 dated Sep. 29, 2015.
Office Action for Japanese Application No. 2014-046409 dated Jan. 5, 2015.
Office Action for Japanese Application No. 2014-046409 dated Jul. 17, 2015.
Invalidation Decision for Chinese Application No. 200680016023.5 dated Mar. 29, 2016.
Office Action for U.S. Appl. No. 15/016,927 dated May 3, 2016.
Office Action for U.S. Appl. No. 14/925,447 dated May 20, 2016.
Notice of Allowance for U.S. Appl. No. 14/684,609 dated May 24, 2016.

* cited by examiner

PX-206

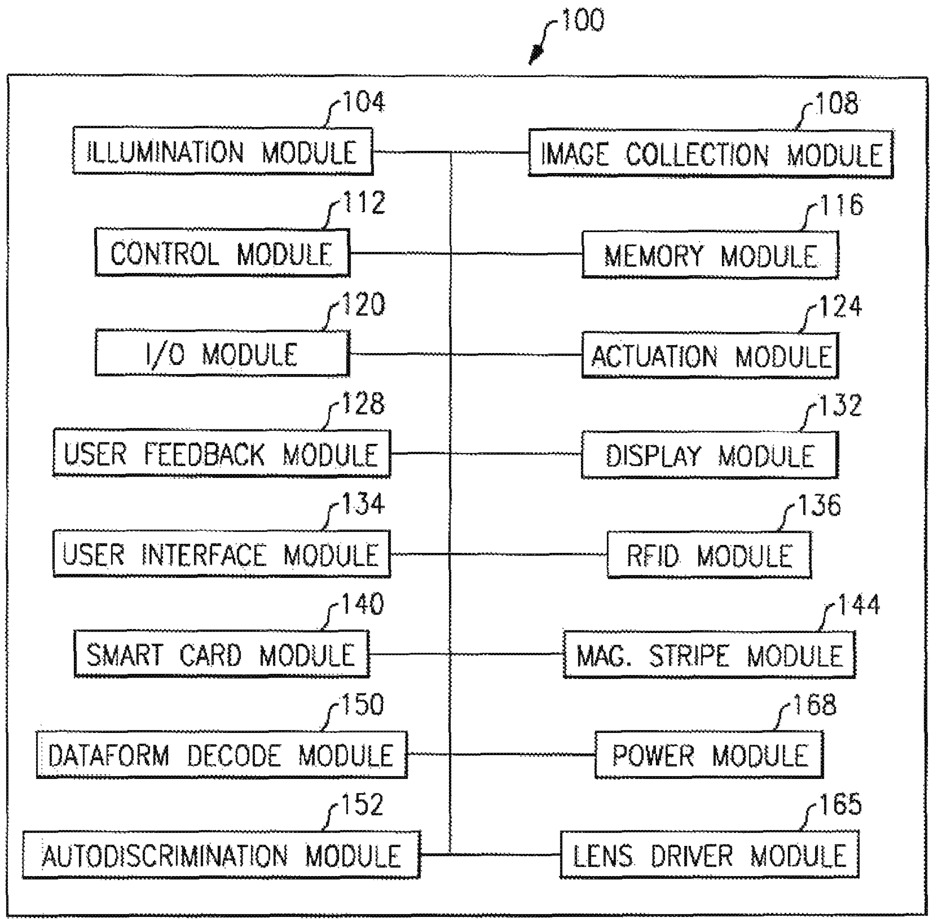


FIG.1A

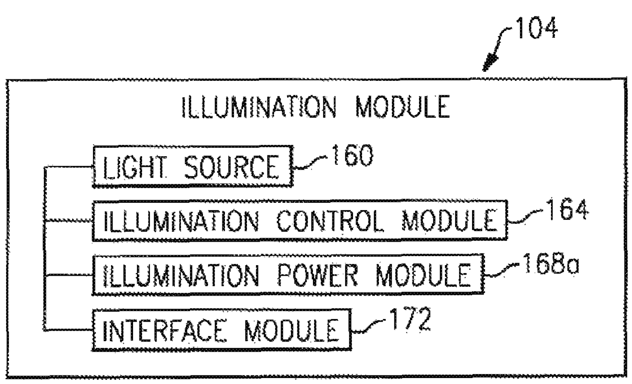


FIG.5A

HONEYWELL-00230381

JA2144

PX-206

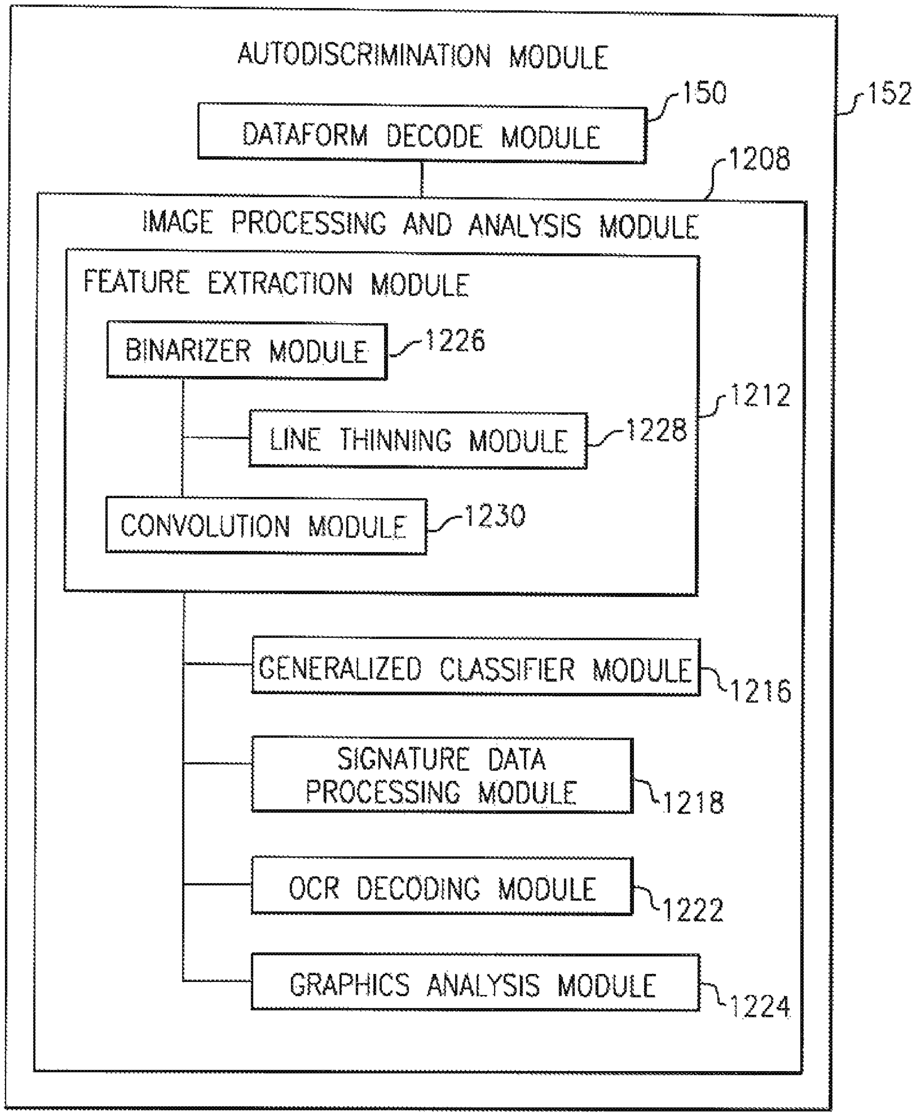

AUTODISCRIMINATION MODULE
DATAFORM DECODE MODULE
150
152
1208
IMAGE PROCESSING AND ANALYSIS MODULE
FEATURE EXTRACTION MODULE
BINARIZER MODULE
1226
1212
LINE THINNING MODULE
1228
CONVOLUTION MODULE
1230
GENERALIZED CLASSIFIER MODULE
1216
SIGNATURE DATA PROCESSING MODULE
1218
OCR DECODING MODULE
1222
GRAPHICS ANALYSIS MODULE
1224

FIG.1B

PX-206

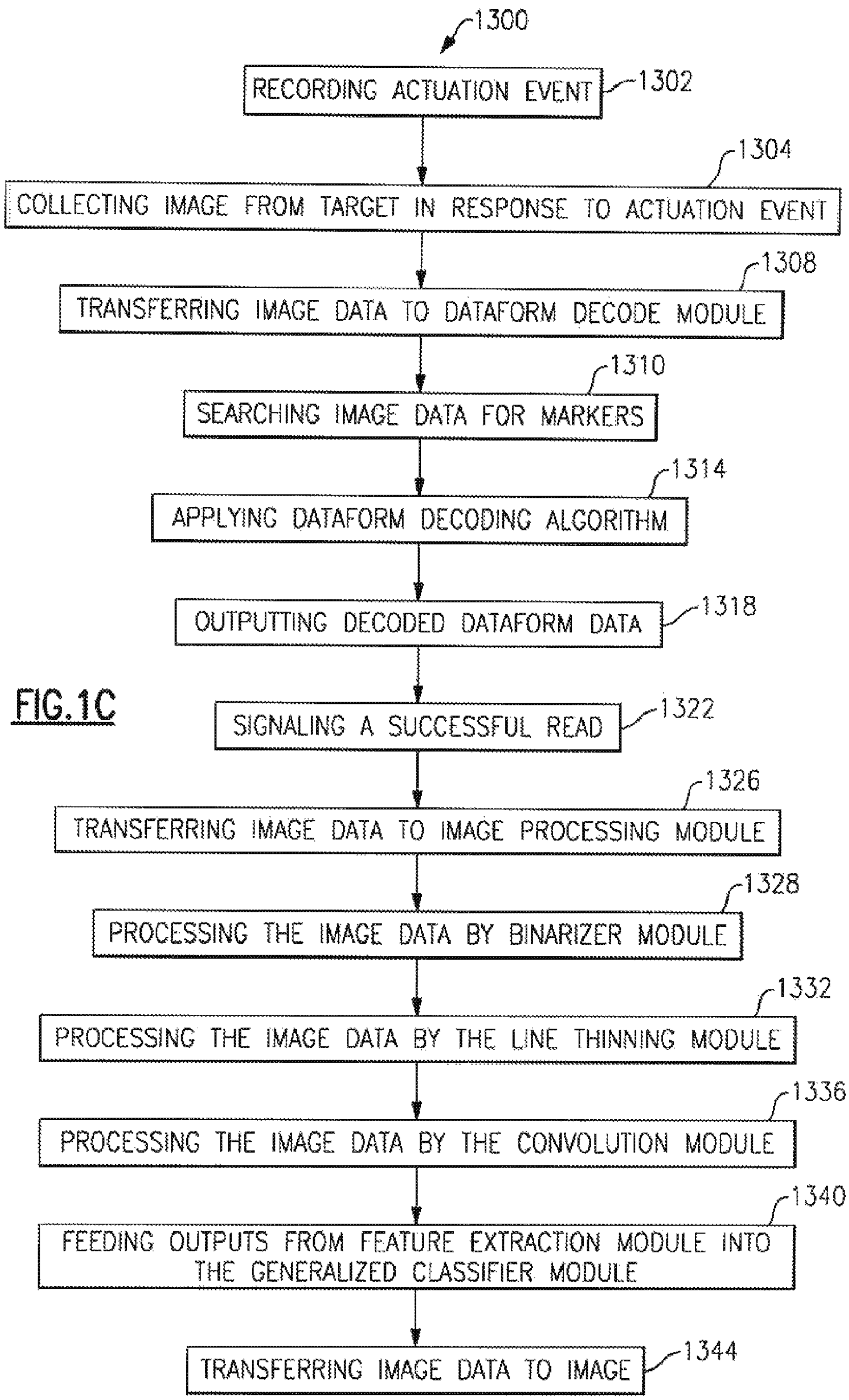

1300
RECORDING ACTUATION EVENT
1302
COLLECTING IMAGE FROM TARGET IN RESPONSE TO ACTUATION EVENT
1304
TRANSFERRING IMAGE DATA TO DATAFORM DECODE MODULE
1308
SEARCHING IMAGE DATA FOR MARKERS
1310
APPLYING DATAFORM DECODING ALGORITHM
1314
OUTPUTTING DECODED DATAFORM DATA
1318
SIGNALING A SUCCESSFUL READ
1322
TRANSFERRING IMAGE DATA TO IMAGE PROCESSING MODULE
1326
PROCESSING THE IMAGE DATA BY BINARIZER MODULE
1328
PROCESSING THE IMAGE DATA BY THE LINE THINNING MODULE
1332
PROCESSING THE IMAGE DATA BY THE CONVOLUTION MODULE
1336
FEEDING OUTPUTS FROM FEATURE EXTRACTION MODULE INTO THE GENERALIZED CLASSIFIER MODULE
1340
TRANSFERRING IMAGE DATA TO IMAGE
1344

FIG.1C

PX-206

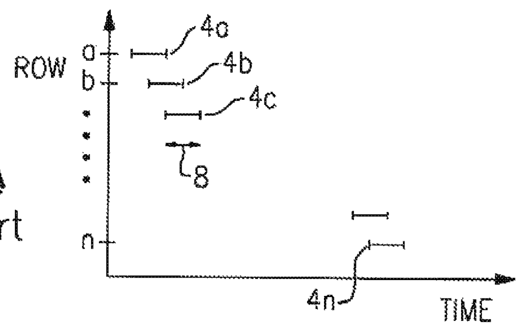


FIG.2A
Prior Art

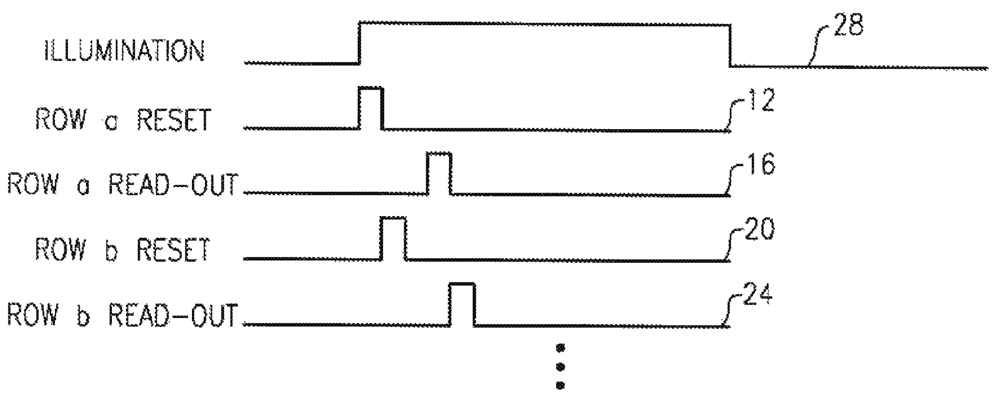


FIG.2B
Prior Art

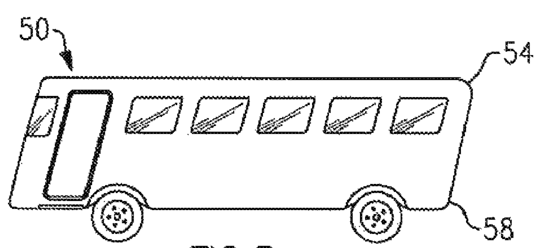


FIG.3
Prior Art

PX-206

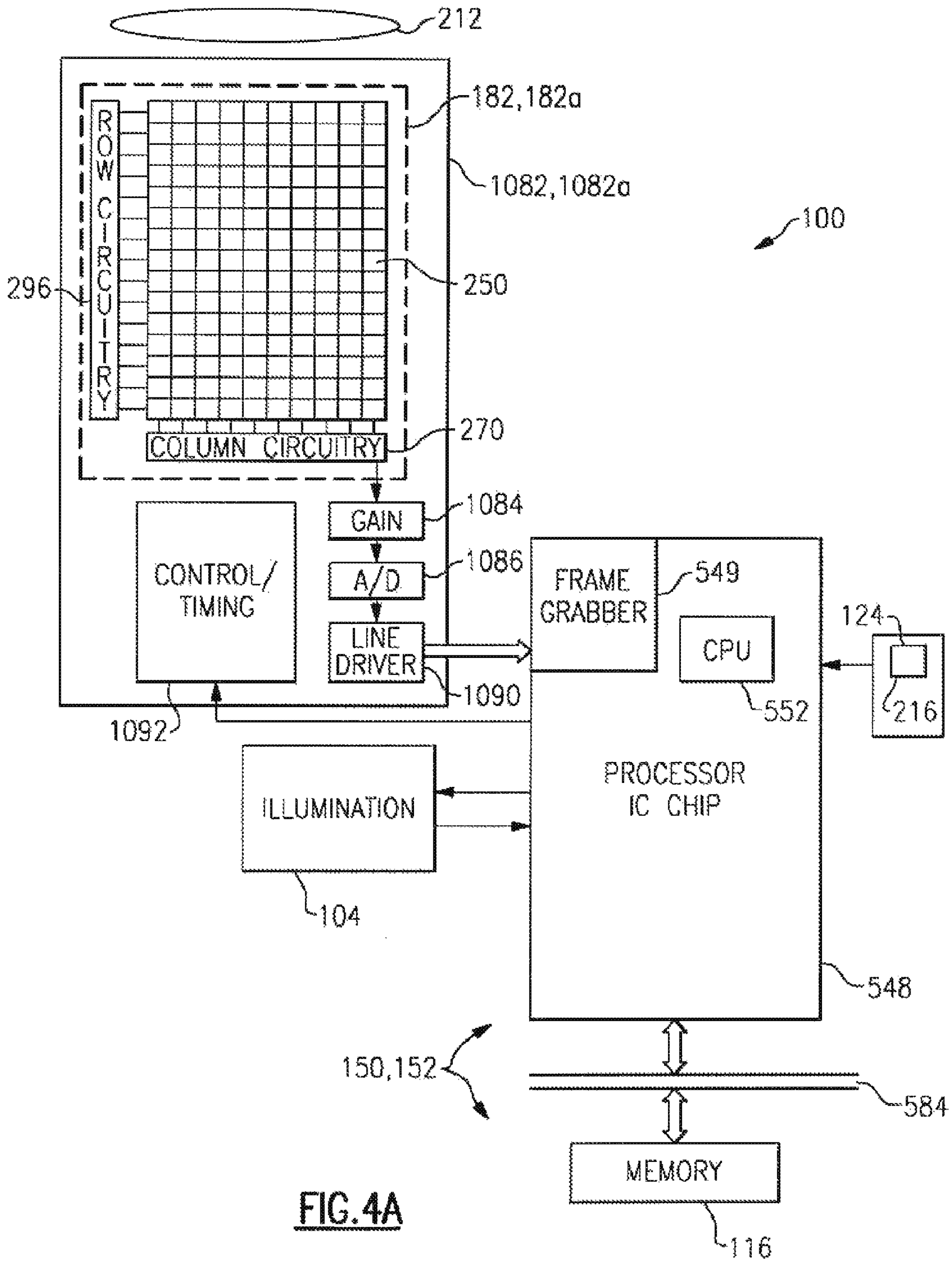
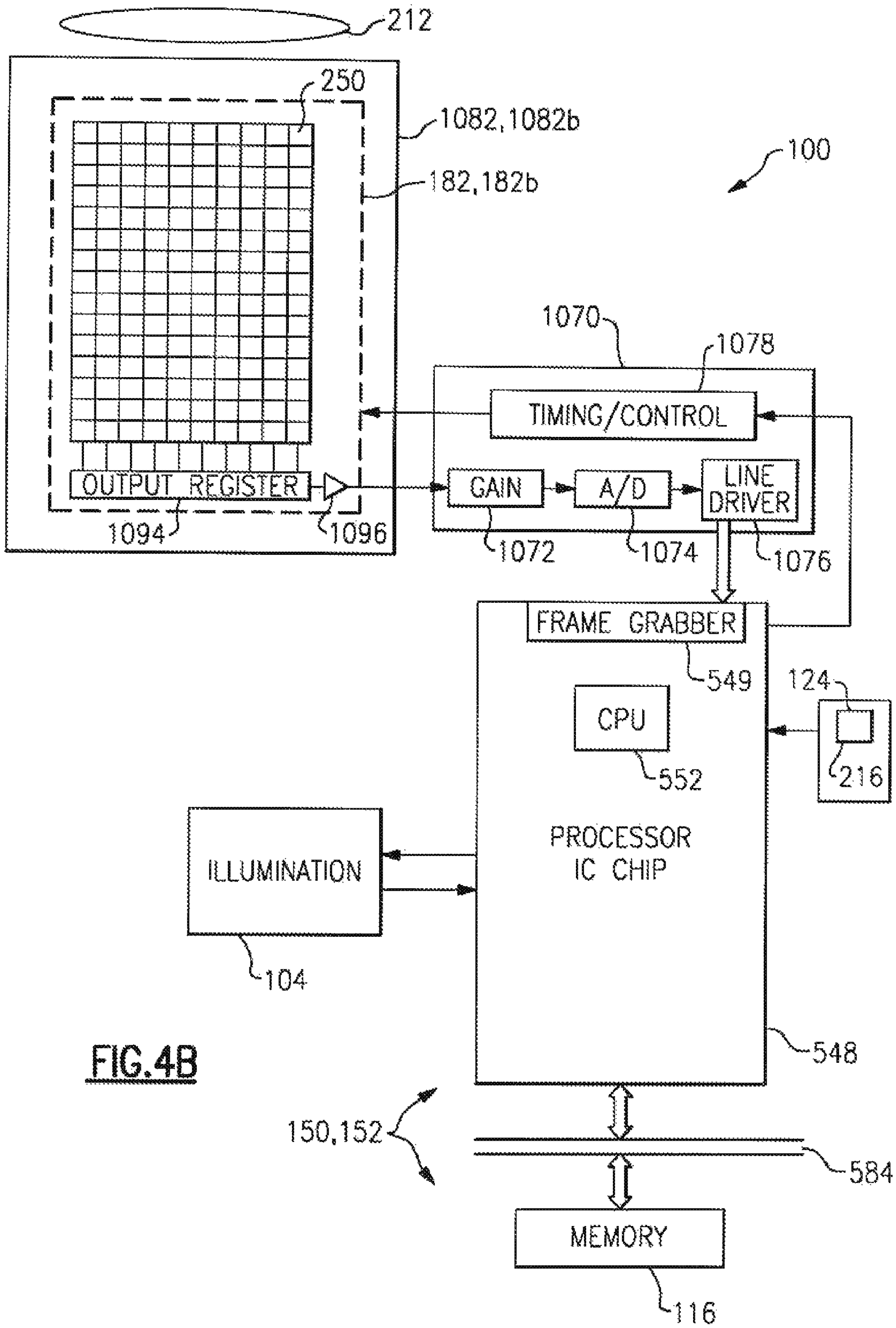

212
182,182a
1082,1082a
100
296
ROW CIRCUITRY
250
COLUMN CIRCUITRY
270
GAIN
1084
A/D
1086
CONTROL/
TIMING
LINE
DRIVER
1090
1092
FRAME
GRABBER
549
CPU
552
124
216
PROCESSOR
IC CHIP
ILLUMINATION
104
548
150,152
584
MEMORY
116

FIG. 4A

PX-206



212
250
1082,1082b
182,182b
100
1070
1078
TIMING/CONTROL
OUTPUT REGISTER
GAIN
A/D
LINE DRIVER
1094
1096
1072
1074
1076
FRAME GRABBER
549
124
CPU
552
216
PROCESSOR IC CHIP
ILLUMINATION
104
548
150,152
584
MEMORY
116

FIG.4B

PX-206

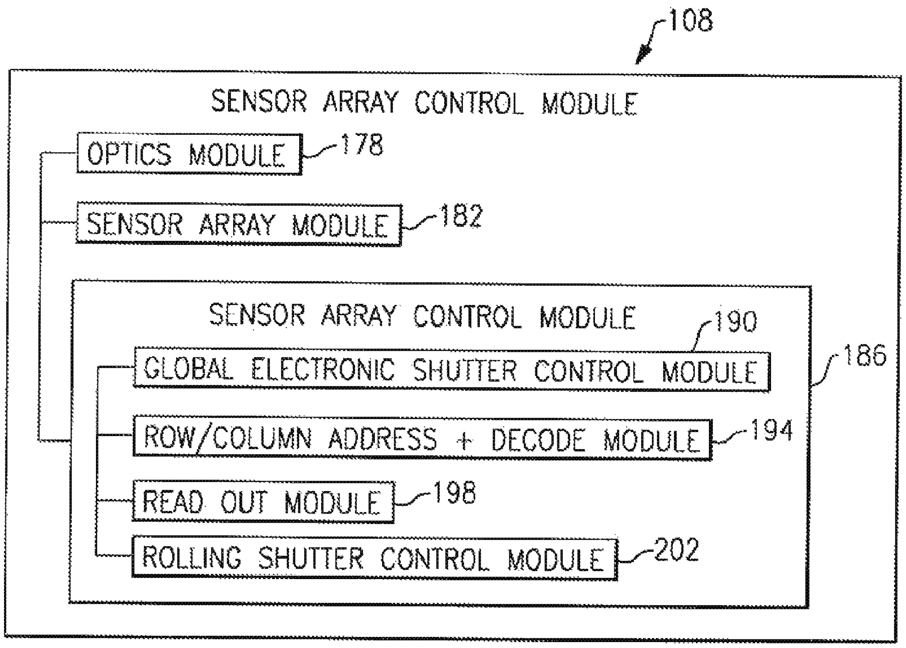


FIG.5B

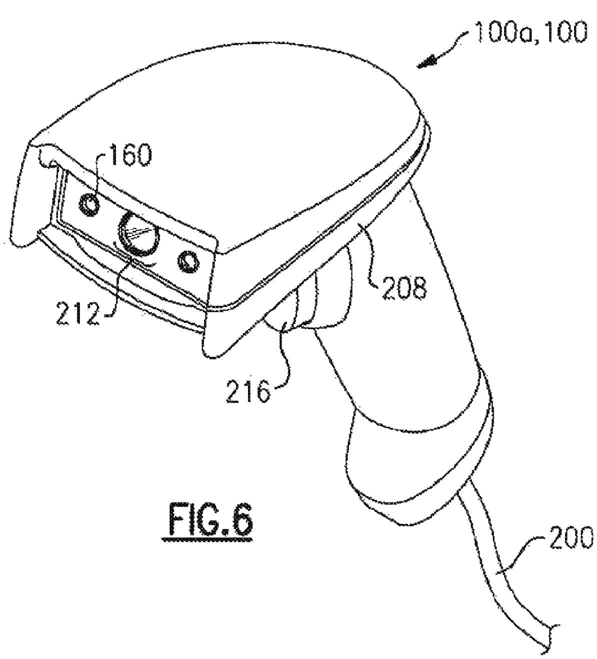


FIG.6

PX-206

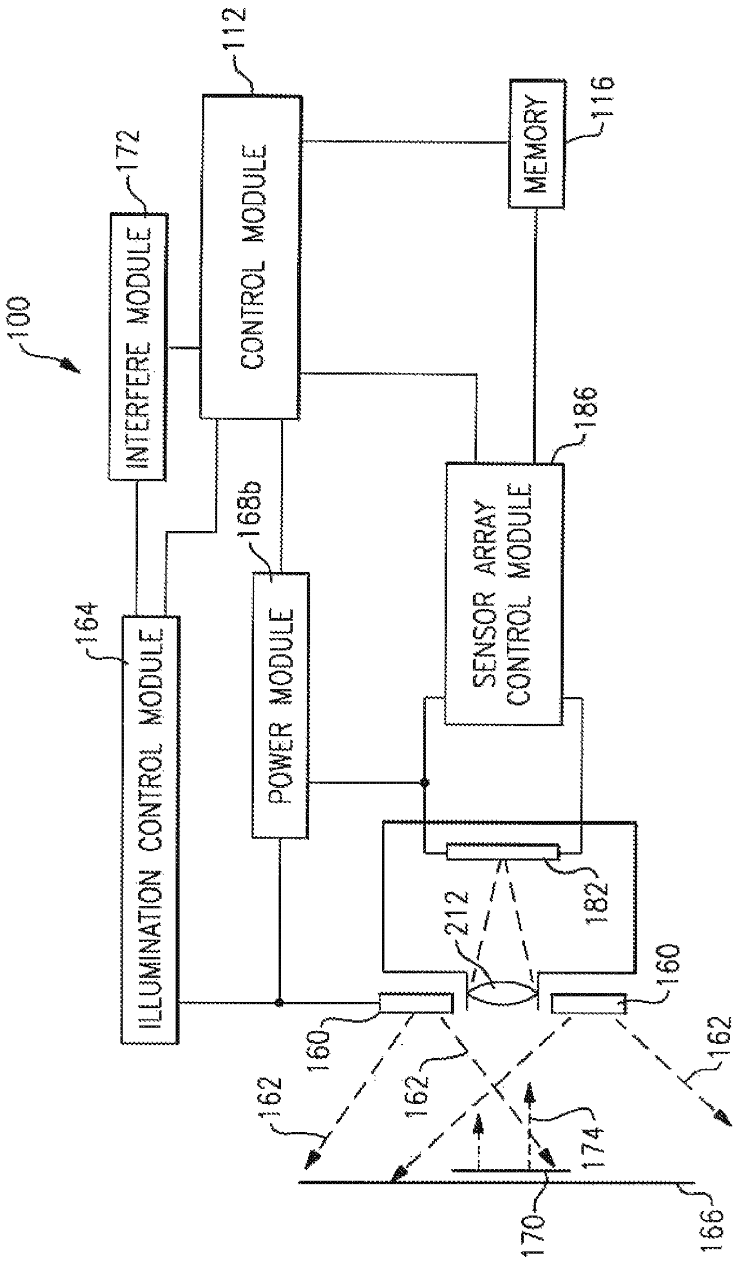

100
INTERFERE MODULE
172
CONTROL MODULE
112
MEMORY
116
186
SENSOR ARRAY CONTROL MODULE
168b
POWER MODULE
164
ILLUMINATION CONTROL MODULE
212
182
160
160
162
162
162
162
174
170
166

FIG.7

PX-206

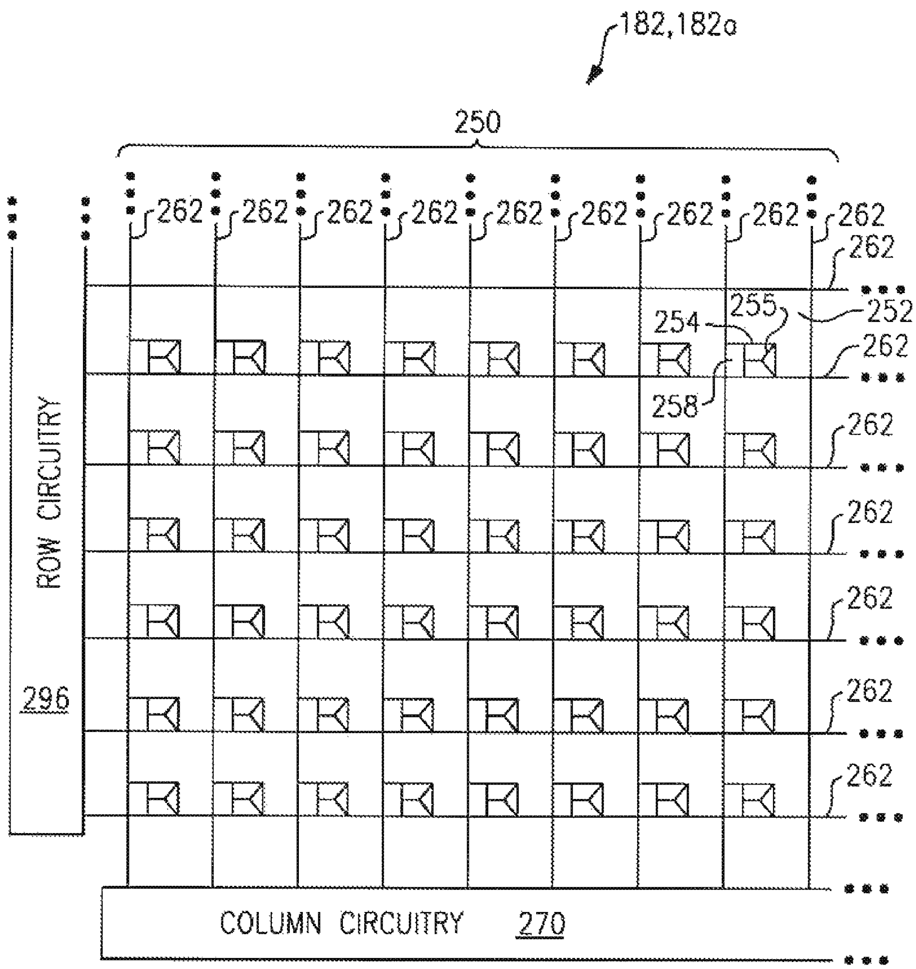


FIG.8A
Prior Art

PX-206

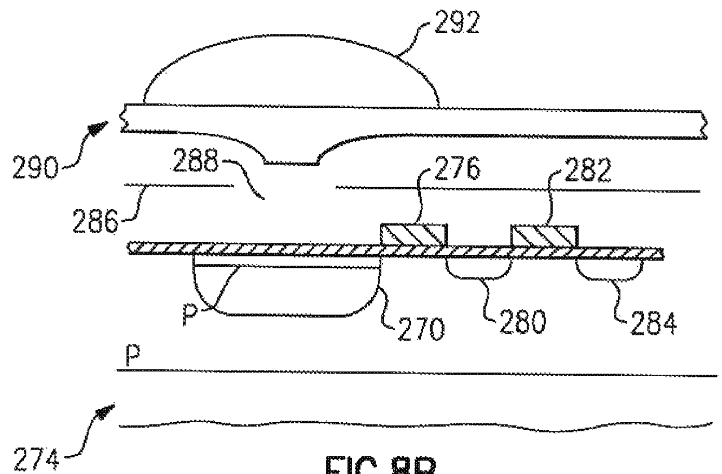


FIG.8B
Prior Art

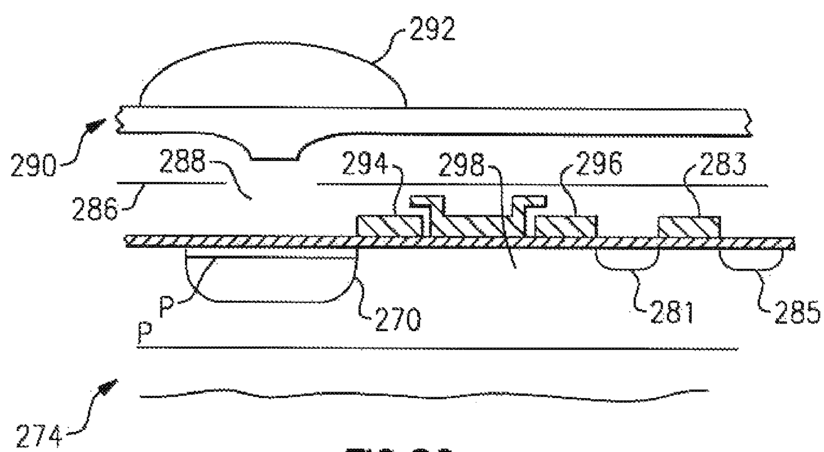


FIG.8C
Prior Art

PX-206

HONEYWELL-00230391

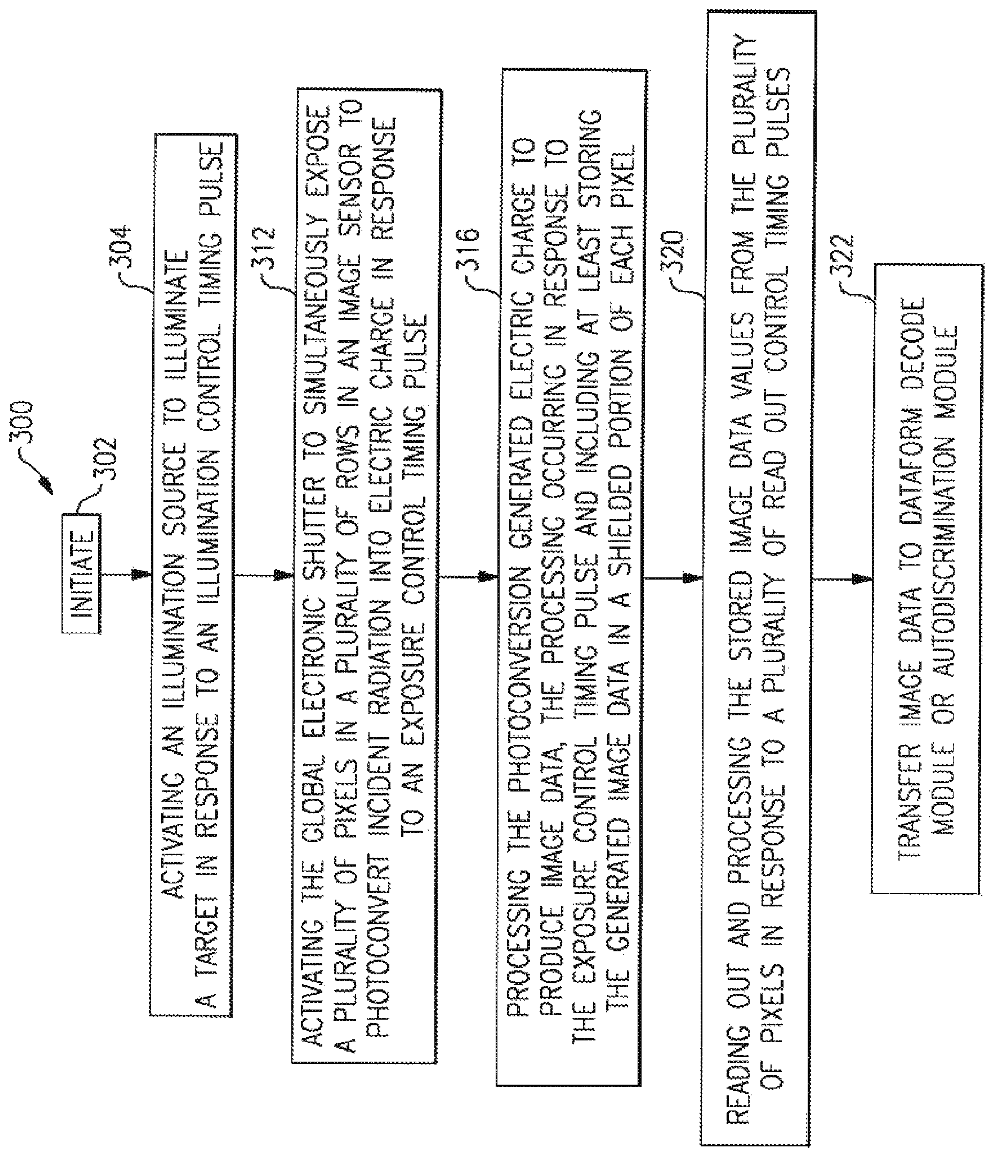


FIG.9

PX-206

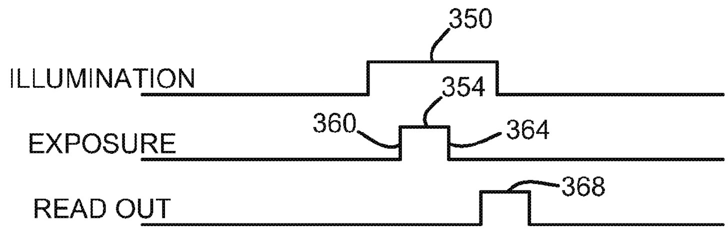


FIG. 10A

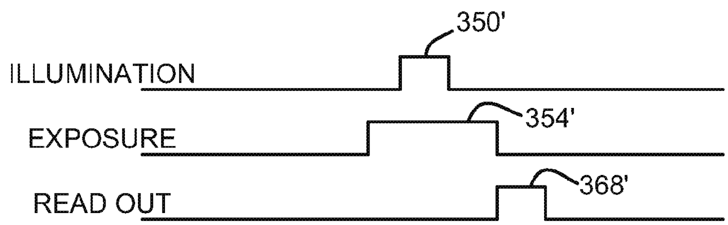


FIG. 10B

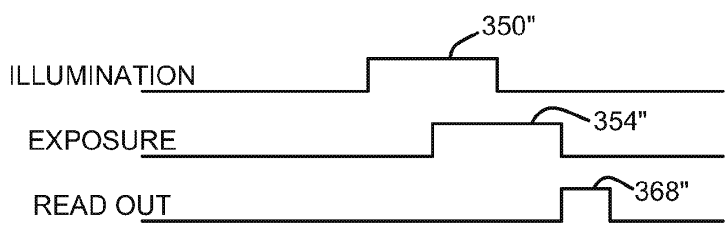


FIG. 10C

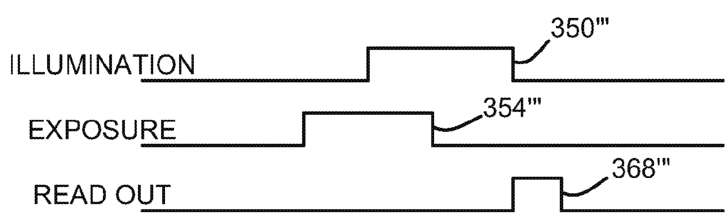


FIG. 10D

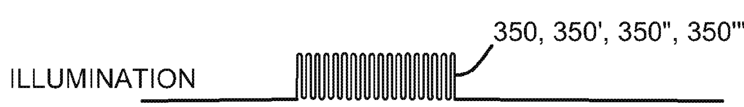


FIG. 10E

PX-206

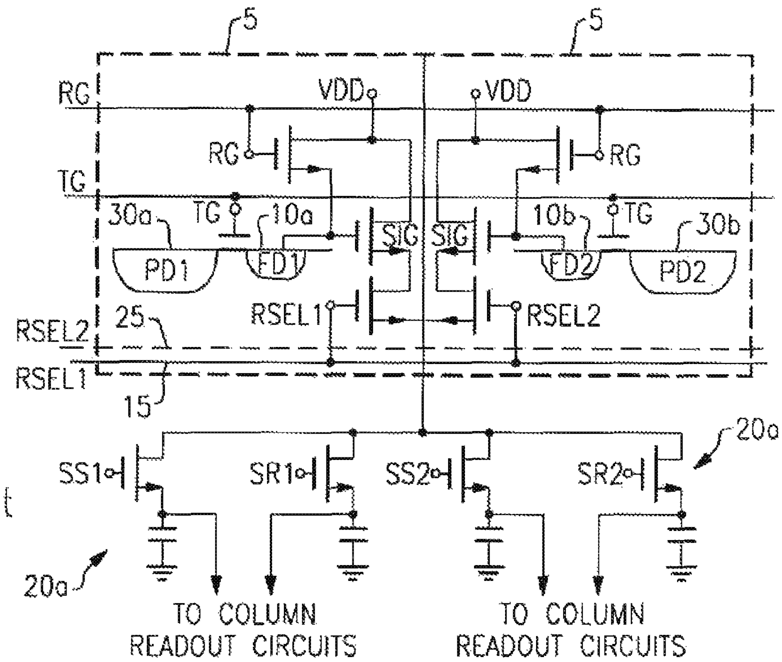


FIG. 11
Prior Art

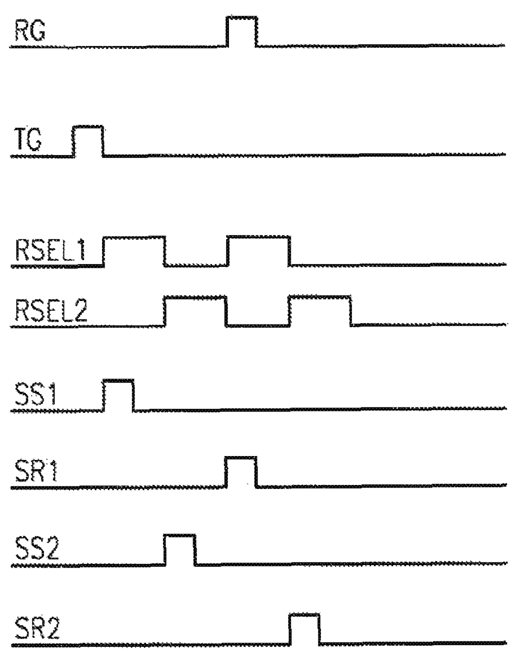


FIG. 12
Prior Art

PX-206

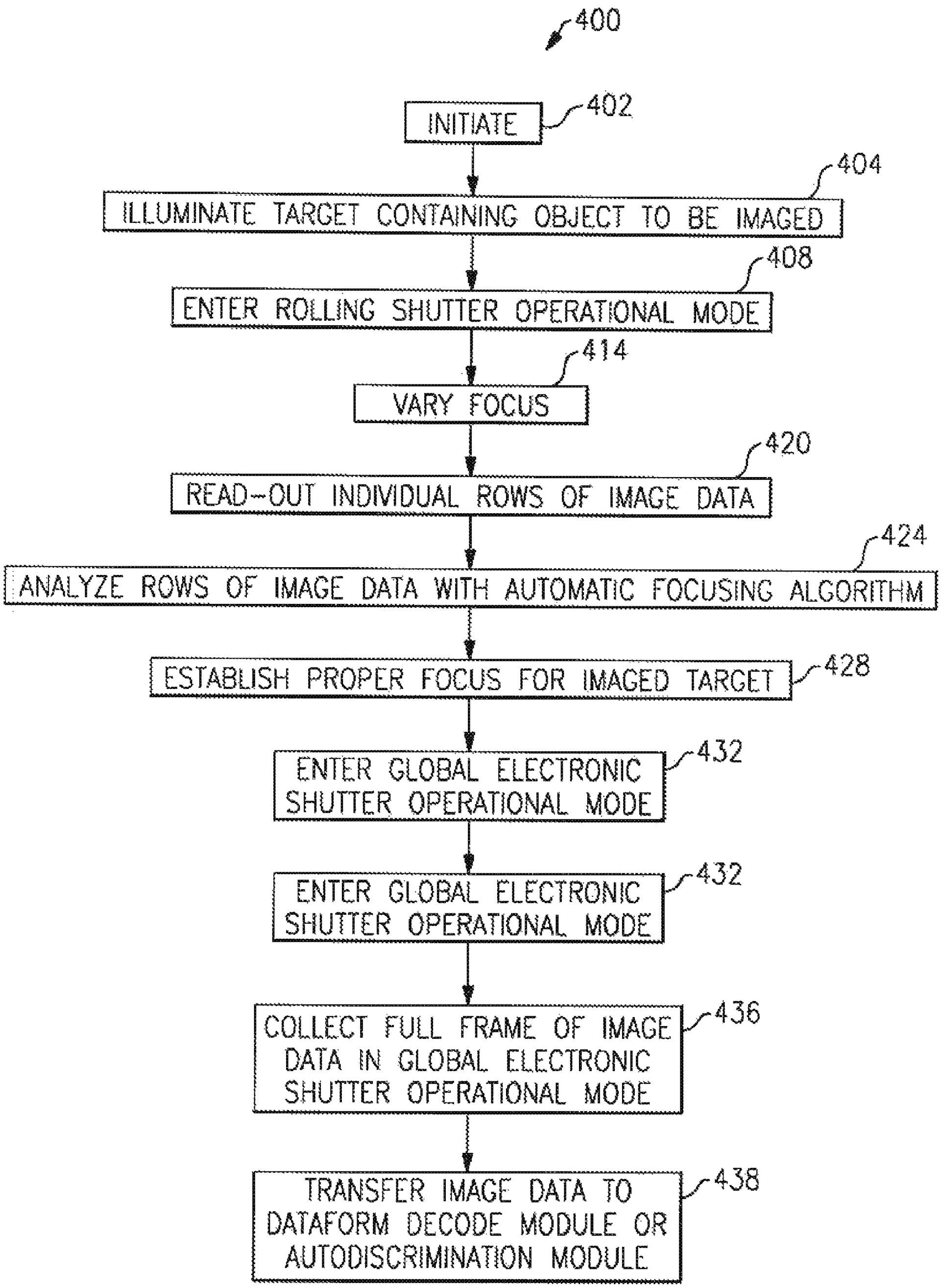

400
INITIATE
402
ILLUMINATE TARGET CONTAINING OBJECT TO BE IMAGED
404
ENTER ROLLING SHUTTER OPERATIONAL MODE
408
VARY FOCUS
414
READ-OUT INDIVIDUAL ROWS OF IMAGE DATA
420
ANALYZE ROWS OF IMAGE DATA WITH AUTOMATIC FOCUSING ALGORITHM
424
ESTABLISH PROPER FOCUS FOR IMAGED TARGET
428
ENTER GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
432
ENTER GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
432
COLLECT FULL FRAME OF IMAGE DATA IN GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
436
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
438

FIG.13

PX-206

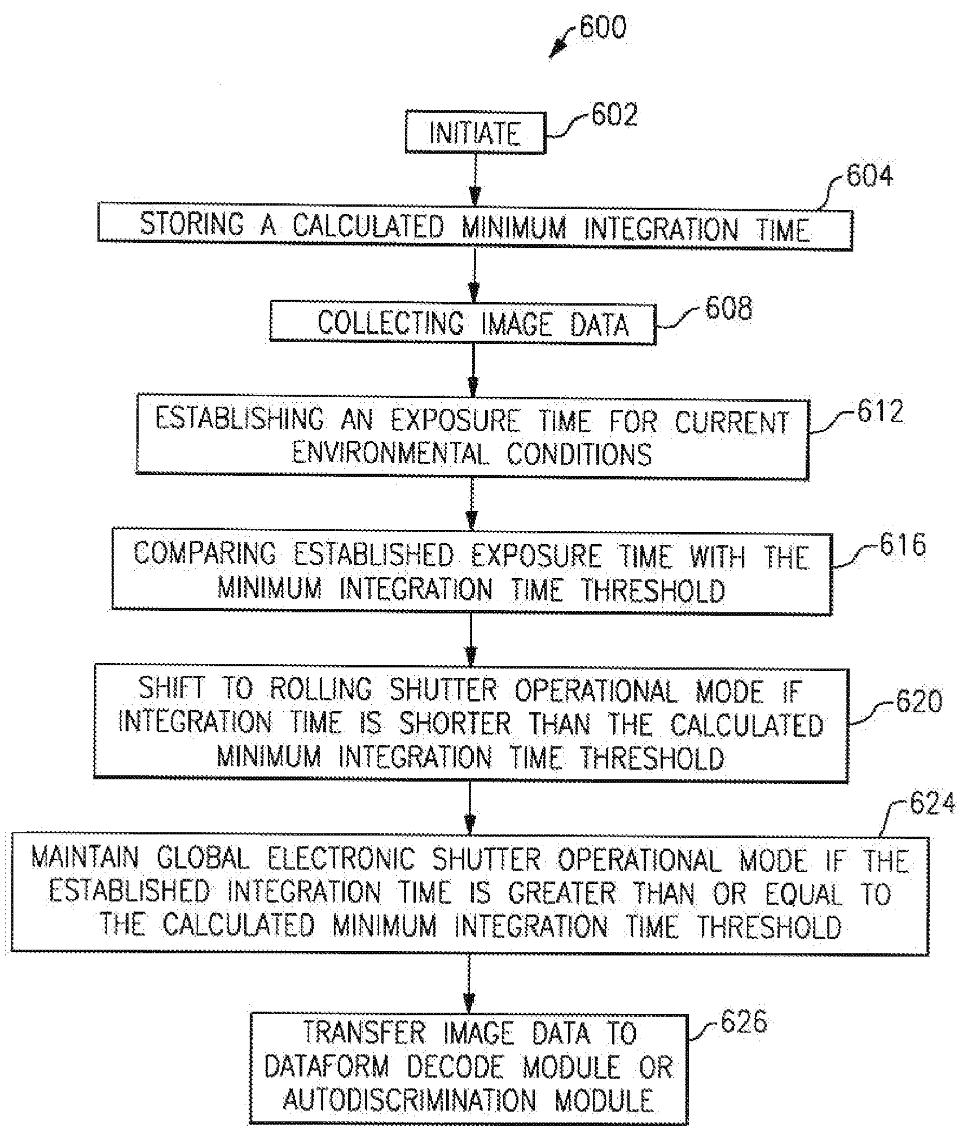

600
INITIATE
602
STORING A CALCULATED MINIMUM INTEGRATION TIME
604
COLLECTING IMAGE DATA
608
ESTABLISHING AN EXPOSURE TIME FOR CURRENT ENVIRONMENTAL CONDITIONS
612
COMPARING ESTABLISHED EXPOSURE TIME WITH THE MINIMUM INTEGRATION TIME THRESHOLD
616
SHIFT TO ROLLING SHUTTER OPERATIONAL MODE IF INTEGRATION TIME IS SHORTER THAN THE CALCULATED MINIMUM INTEGRATION TIME THRESHOLD
620
MAINTAIN GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE IF THE ESTABLISHED INTEGRATION TIME IS GREATER THAN OR EQUAL TO THE CALCULATED MINIMUM INTEGRATION TIME THRESHOLD
624
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
626

FIG.14

PX-206

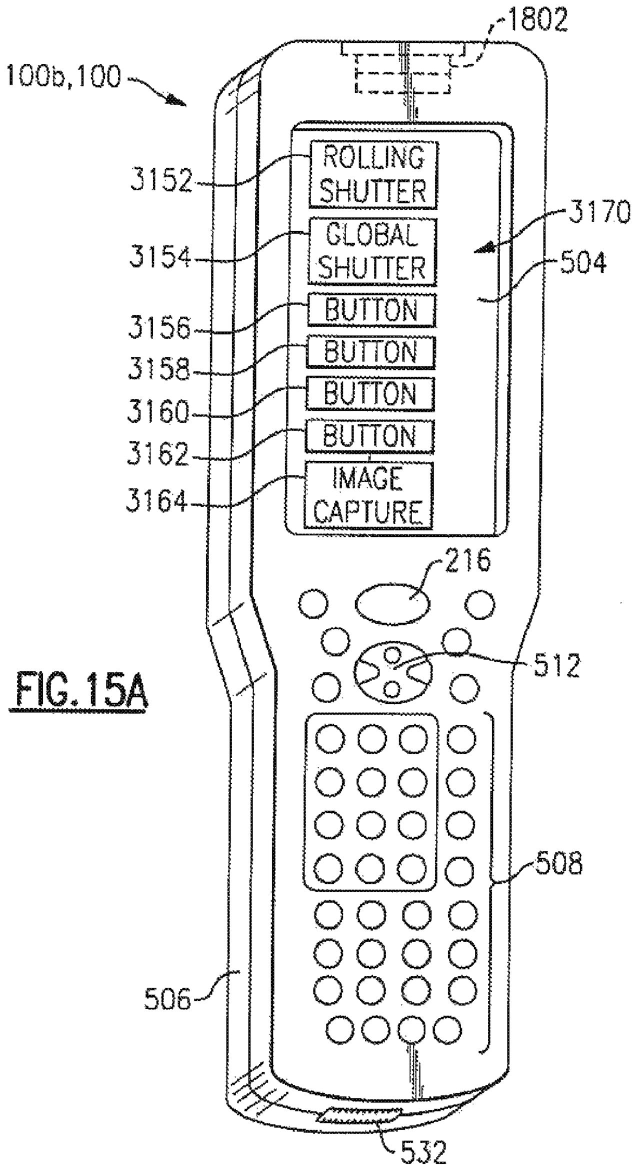


FIG. 15A

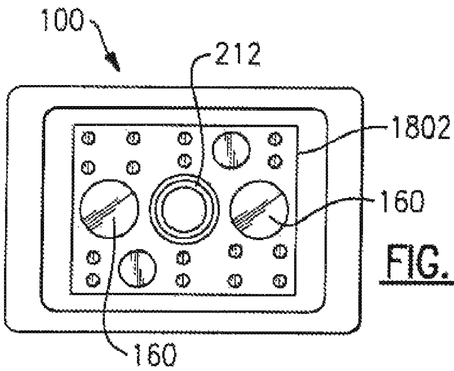


FIG. 15B

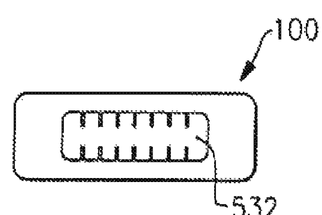


FIG. 15C

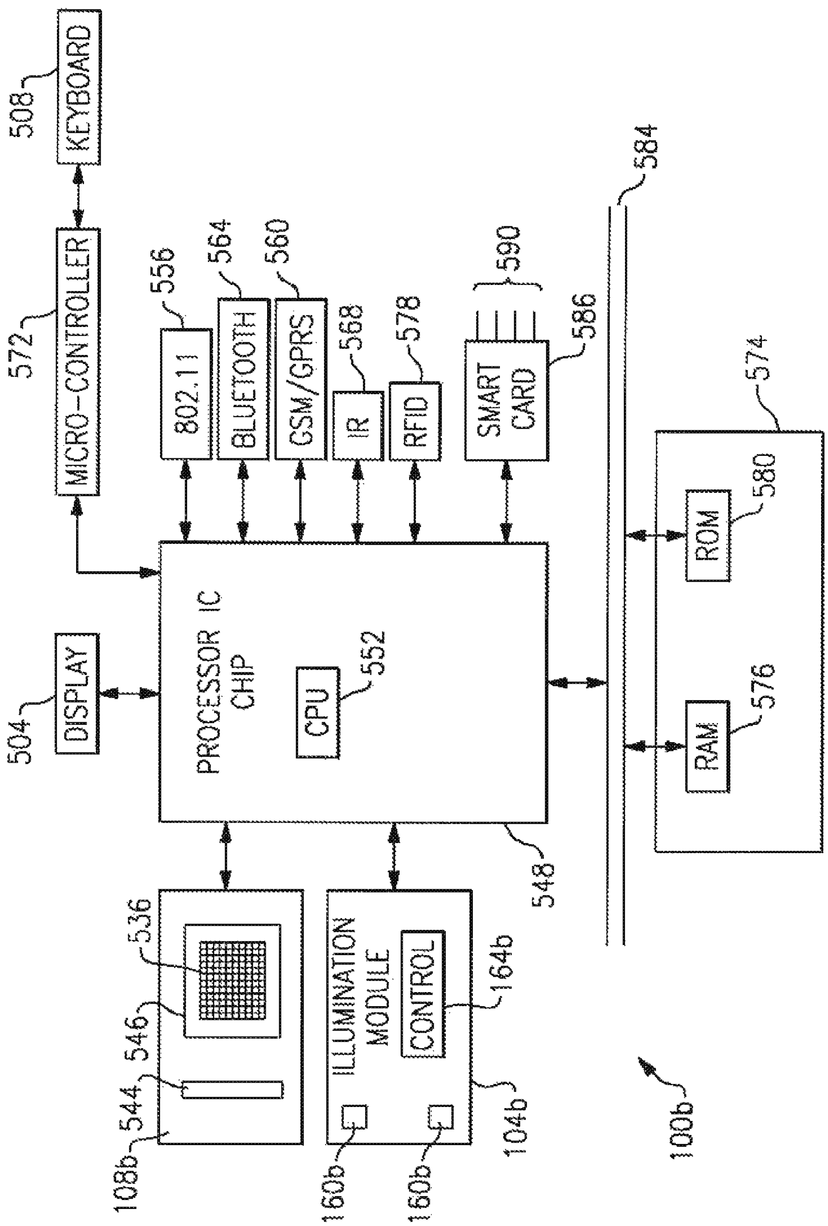

KEYBOARD
508
MICRO-CONTROLLER
572
802.11
556
BLUETOOTH
564
GSM/GPRS
560
IR
568
RFID
578
SMART CARD
586
590
584
574
ROM
580
RAM
576
PROCESSOR IC CHIP
CPU
552
DISPLAY
504
548
536
546
544
108b
ILLUMINATION MODULE
CONTROL
164b
104b
160b
160b
100b

FIG.16

PX-206

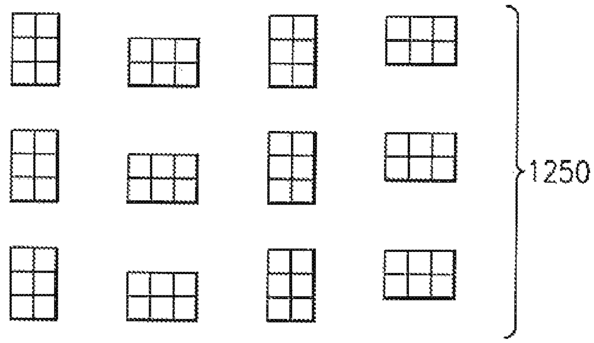


FIG.17A

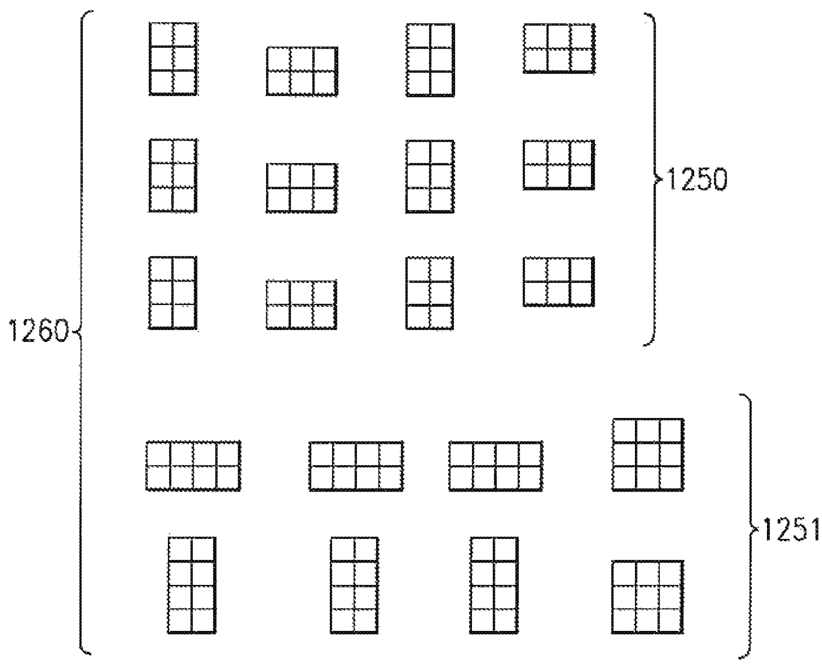


FIG.17B

PX-206

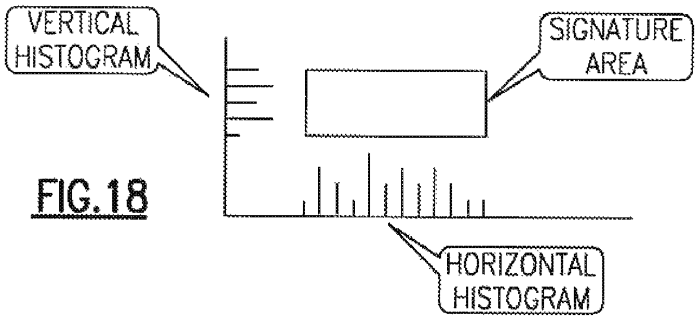


FIG.18

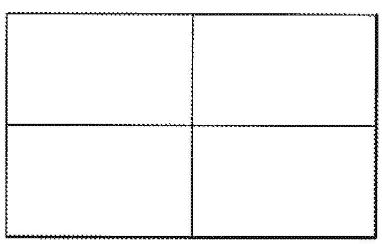


FIG.19A

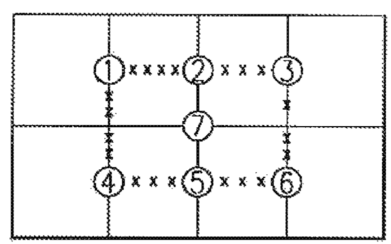


FIG.19B

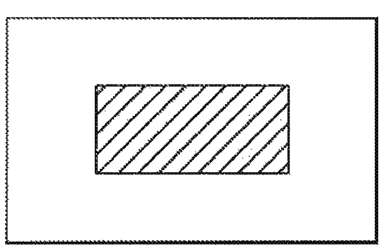


FIG.19C

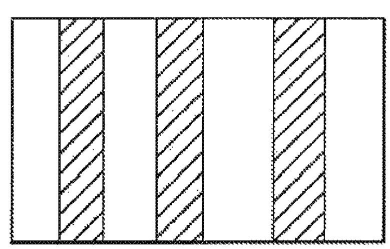
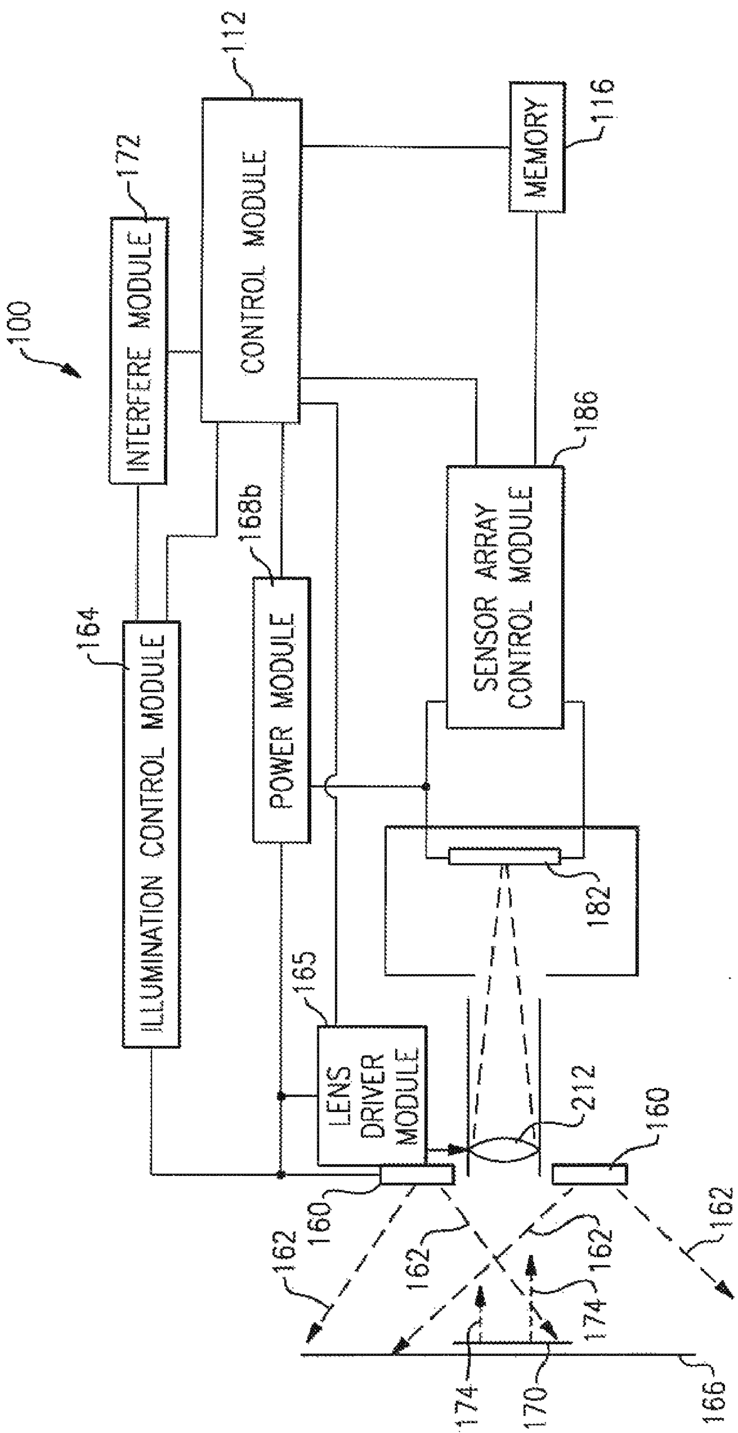


FIG.19D



100
INTERFERE MODULE
172
CONTROL MODULE
112
MEMORY
116
186
SENSOR ARRAY CONTROL MODULE
168b
POWER MODULE
164
ILLUMINATION CONTROL MODULE
182
165
LENS DRIVER MODULE
212
160
160
162
162
162
162
174
174
170
166

FIG.20

PX-206

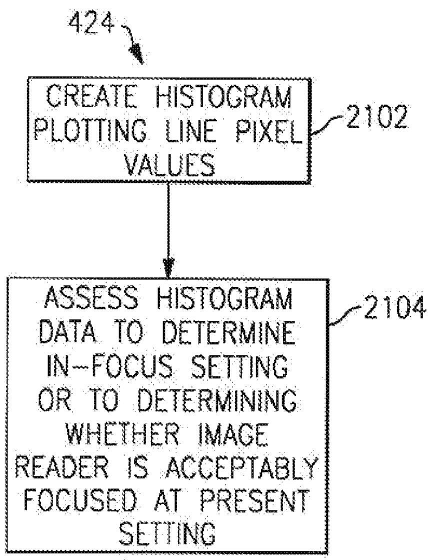


FIG.21

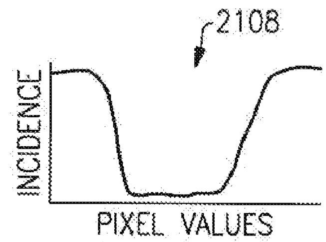


FIG.22A

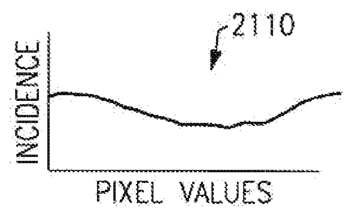


FIG.22B

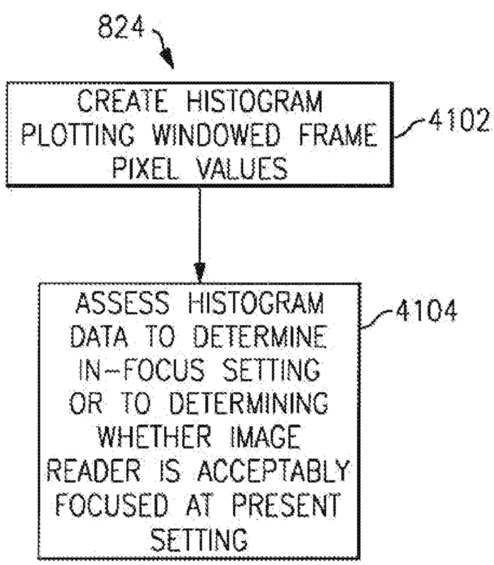


FIG.29

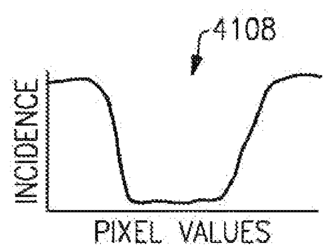


FIG.30A

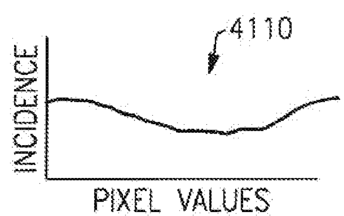


FIG.30B

PX-206

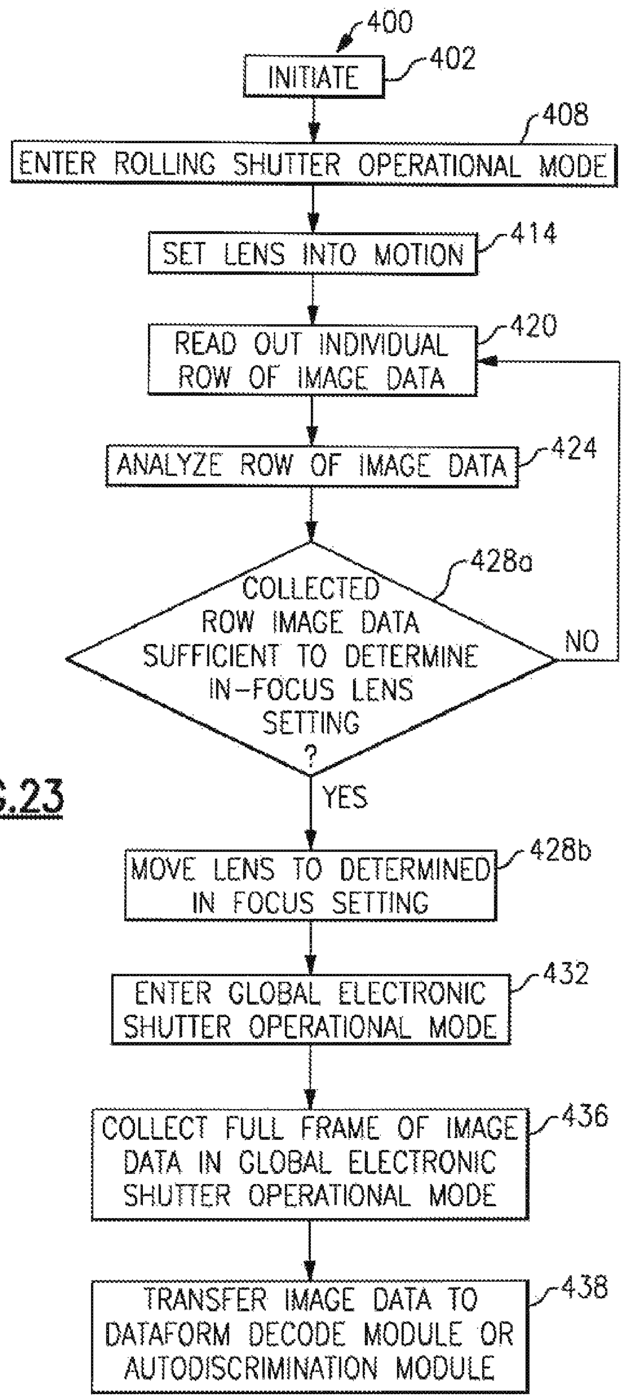

400
INITIATE
402
ENTER ROLLING SHUTTER OPERATIONAL MODE
408
SET LENS INTO MOTION
414
READ OUT INDIVIDUAL ROW OF IMAGE DATA
420
ANALYZE ROW OF IMAGE DATA
424
COLLECTED ROW IMAGE DATA SUFFICIENT TO DETERMINE IN-FOCUS LENS SETTING ?
428a
NO
YES
MOVE LENS TO DETERMINED IN FOCUS SETTING
428b
ENTER GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
432
COLLECT FULL FRAME OF IMAGE DATA IN GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
436
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
438

FIG.23

PX-206

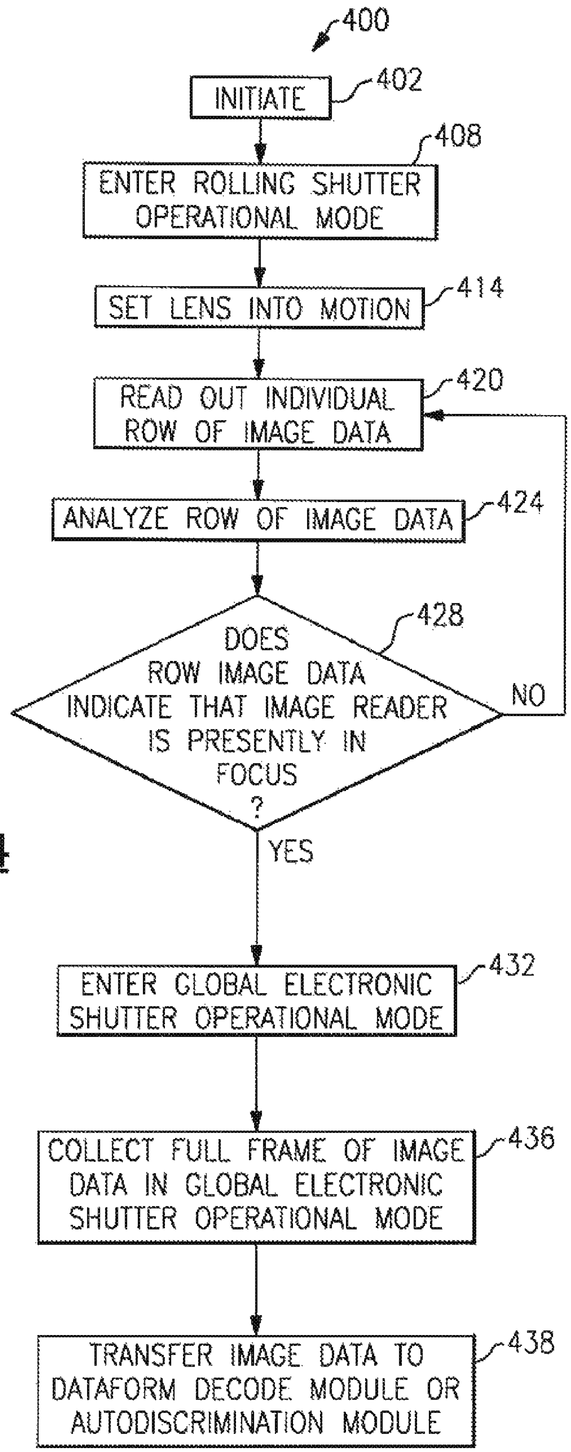

400
INITIATE
402
ENTER ROLLING SHUTTER OPERATIONAL MODE
408
SET LENS INTO MOTION
414
READ OUT INDIVIDUAL ROW OF IMAGE DATA
420
ANALYZE ROW OF IMAGE DATA
424
DOES ROW IMAGE DATA INDICATE THAT IMAGE READER IS PRESENTLY IN FOCUS ?
428
NO
YES
ENTER GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
432
COLLECT FULL FRAME OF IMAGE DATA IN GLOBAL ELECTRONIC SHUTTER OPERATIONAL MODE
436
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
438

FIG.24

PX-206

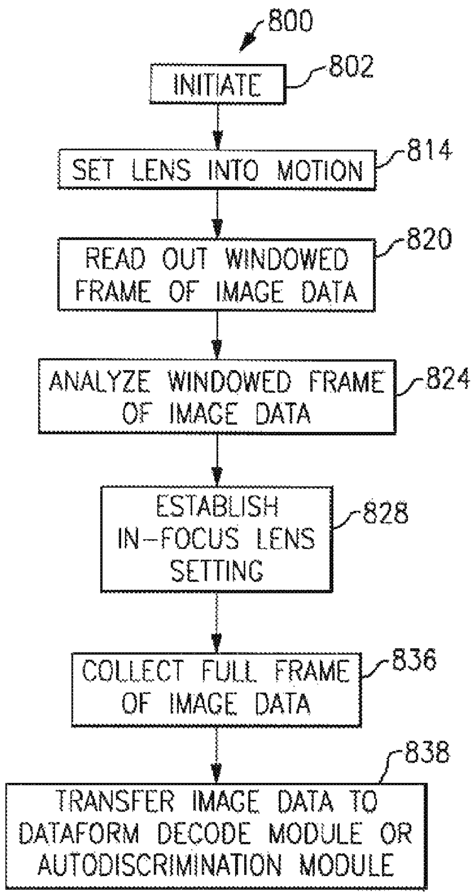


FIG.25

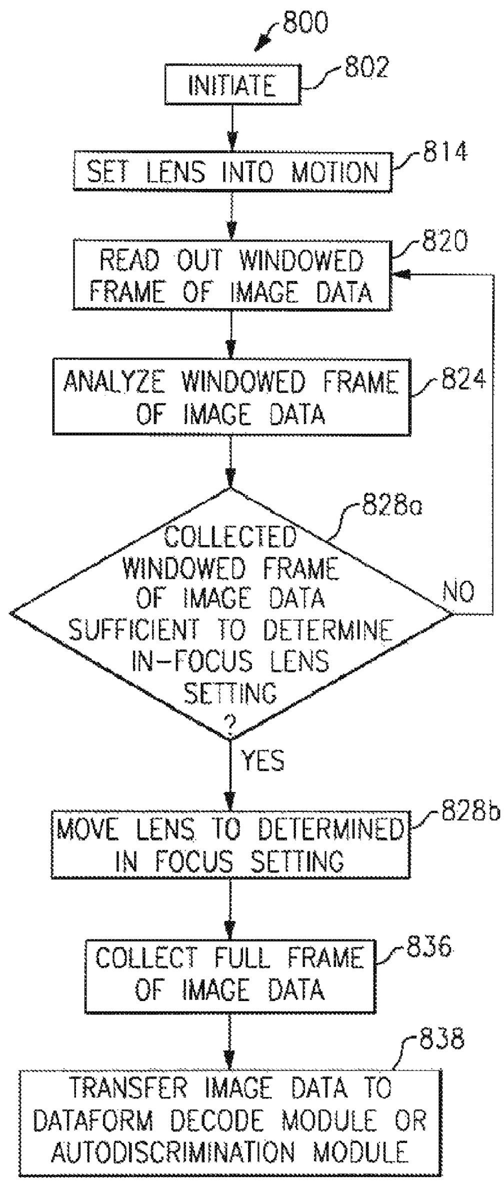


FIG.26

PX-206

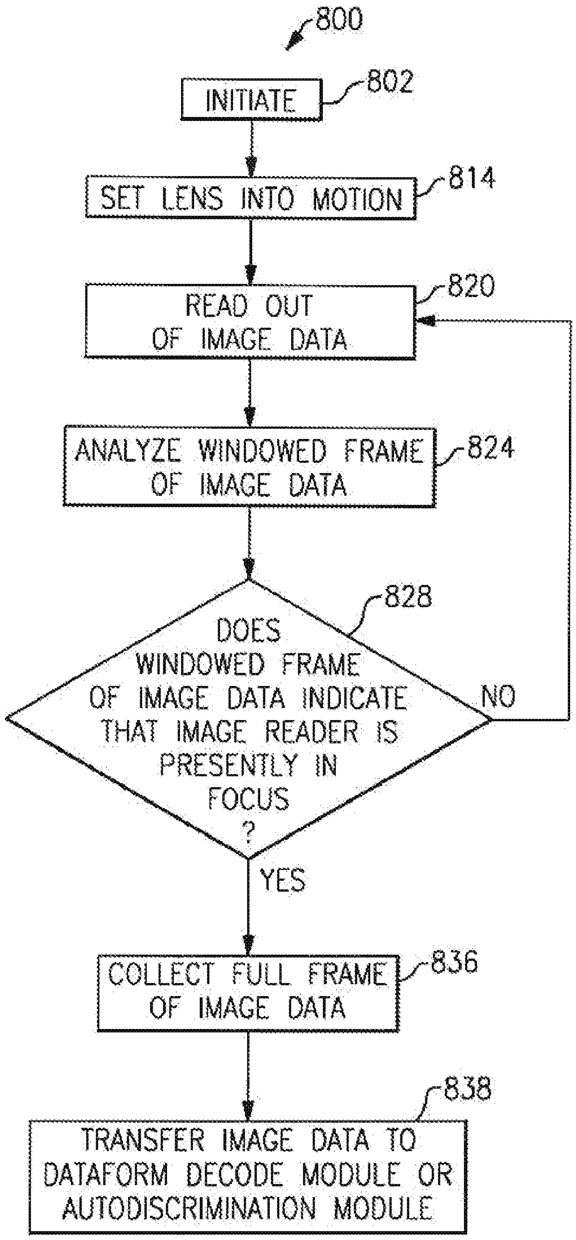

800
INITIATE
802
SET LENS INTO MOTION
814
READ OUT OF IMAGE DATA
820
ANALYZE WINDOWED FRAME OF IMAGE DATA
824
DOES WINDOWED FRAME OF IMAGE DATA INDICATE THAT IMAGE READER IS PRESENTLY IN FOCUS ?
828
NO
YES
COLLECT FULL FRAME OF IMAGE DATA
836
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
838

FIG.27

PX-206

FIG.28A

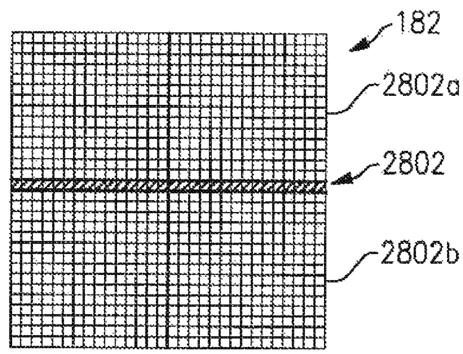


FIG.28B

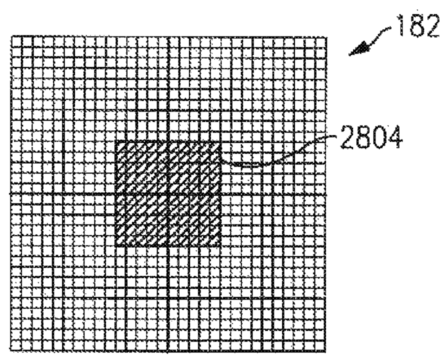
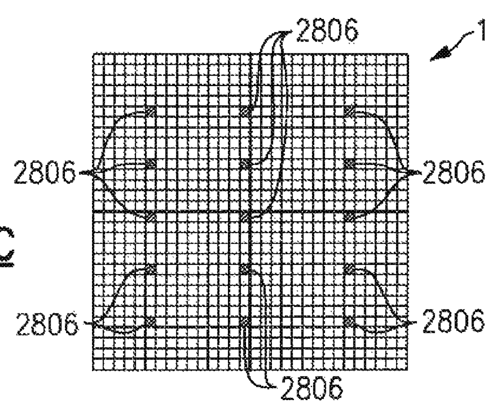


FIG.28C



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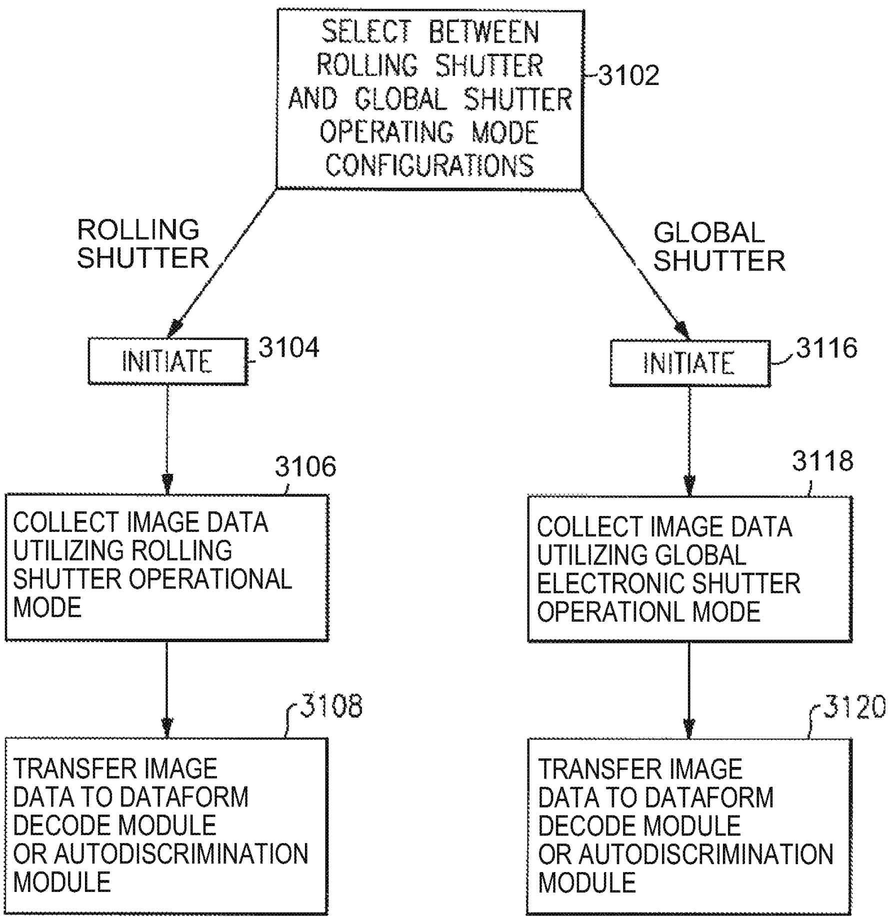
SELECT BETWEEN ROLLING SHUTTER AND GLOBAL SHUTTER OPERATING MODE CONFIGURATIONS
3102
ROLLING SHUTTER
GLOBAL SHUTTER
INITIATE
3104
INITIATE
3116
3106
COLLECT IMAGE DATA UTILIZING ROLLING SHUTTER OPERATIONAL MODE
3118
COLLECT IMAGE DATA UTILIZING GLOBAL ELECTRONIC SHUTTER OPERATIONL MODE
3108
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
3120
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE

FIG.31

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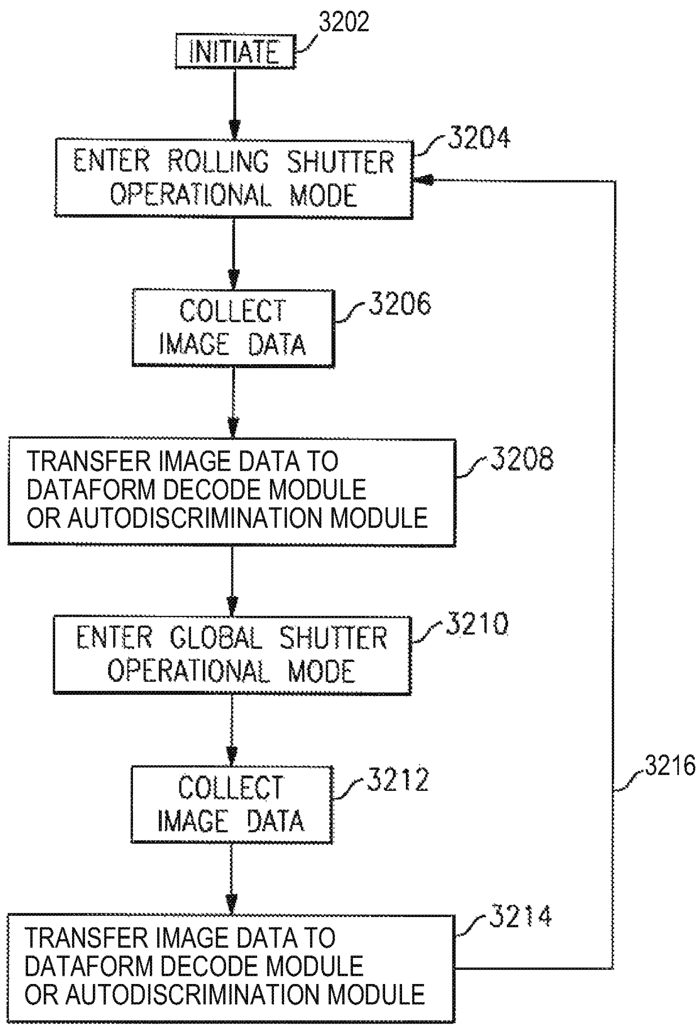
3202
INITIATE
3204
ENTER ROLLING SHUTTER OPERATIONAL MODE
3206
COLLECT IMAGE DATA
3208
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
3210
ENTER GLOBAL SHUTTER OPERATIONAL MODE
3212
COLLECT IMAGE DATA
3214
TRANSFER IMAGE DATA TO DATAFORM DECODE MODULE OR AUTODISCRIMINATION MODULE
3216

FIG.32

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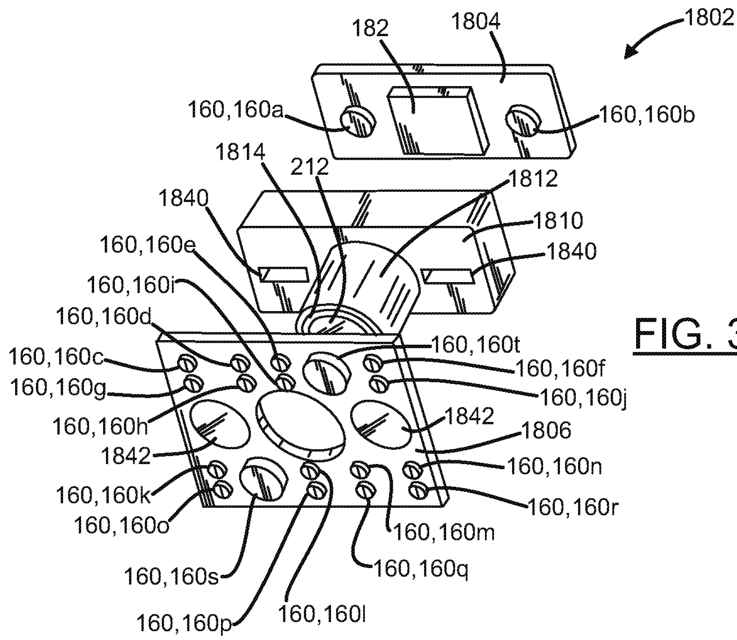

FIG. 33

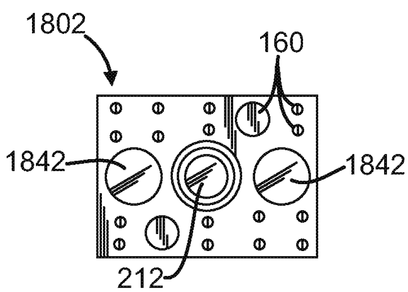

FIG. 34

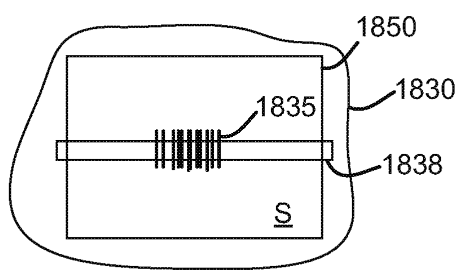

FIG. 36

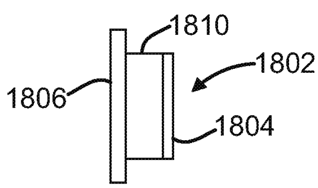

FIG. 35

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EMBODIMENT	AIMING BANK 1 LEDS 160A, 160B	BANK 2 LEDS 160C, 160E, 160H, 160J, 160L, 160N, 160O, 160Q	BANK 3 LEDS 160D, 160F, 160G, 160I, 160K, 160M, 160P, 160R	BANK 4 LEDS 160AS, 160T
1	GREEN EMITTING (GREEN)	RED EMITTING (RED)	BLUE EMITTING (BLUE)	WHITE EMITTING (WHITE)
2	GREEN	RED	RED	RED
3	RED	RED	RED	RED
4	GREEN	RED	GREEN	BLUE
5	BLUE	WHITE	WHITE	RED
6	GREEN	WHITE	RED	RED
7	WHITE	RED	RED	RED
8	GREEN	RED	RED	RED

FIG. 37

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IMAGE READER COMPRISING CMOS BASED IMAGE SENSOR ARRAY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/052,768, filed Mar. 21, 2011, (now U.S. Pat. No. 8,733,660) entitled "Image Reader Comprising CMOS Based Image Sensor Array," which is a divisional of U.S. patent application Ser. No. 12/534,664, filed Aug. 3, 2009, (now U.S. Pat. No. 7,909,257) entitled "Apparatus Having Coordinated Exposure Period and Illumination Period," which is incorporated by reference herein in its entirety, which is a divisional of U.S. patent application Ser. No. 11/077,975, filed Mar. 11, 2005, (now U.S. Pat. No. 7,568,628) entitled "Apparatus Having Coordinated Exposure Period and Illumination Period," which is incorporated herein by reference in its entirety. This application is related to U.S. patent application Ser. No. 11/077,976, filed Mar. 11, 2005, (now U.S. Pat. No. 7,611,060) entitled "System and Method to Automatically Focus an Image Reader," which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The invention relates to image data collection in general and particularly to an image data collector with coordinated illumination and global shutter control.

BACKGROUND OF THE INVENTION

Many traditional imager readers, such as hand held and fixed mounted bar code and machine code readers, employ charge-coupled device (CCDs) based image sensors. A CCD based image sensor contains an array of electrically coupled light sensitive photodiodes that convert incident light energy into packets of electric charge. In operation, the charge packets are shifted out of the CCD imager sensor for subsequent processing.

Some image readers employ CMOS based image sensors as an alternative imaging technology. As with CCDs, CMOS based image sensors contain arrays of light sensitive photodiodes that convert incident light energy into electric charge. Unlike CCDs, however, CMOS based image sensors allow each pixel in a two-dimensional array to be directly addressed. One advantage of this is that sub-regions of a full frame of image data can be independently accessed. Another advantage of CMOS based image sensors is that in general they have lower costs per pixel. This is primarily due to the fact that CMOS image sensors are made with standard CMOS processes in high volume wafer fabrication facilities that produce common integrated circuits such as microprocessors and the like. In addition to lower cost, the common fabrication process means that a CMOS pixel array can be integrated on a single circuit with other standard electronic devices such as clock drivers, digital logic, analog/digital converters and the like. This in turn has the further advantage of reducing space requirements and lowering power usage.

CMOS based image readers have traditionally employed rolling shutters to expose pixels in the sensor array. In a rolling shutter architecture, rows of pixels are activated and read out in sequence. The exposure or integration time for a pixel is the time between a pixel being reset and its value being read out. This concept is presented in FIG. **2**A. In FIG. **2**A, the exposure for each of the rows "a" though "n" is

diagrammatically represented by the bars **4***a* . . . **4***n* (generally **4**). The horizontal extent **8** of each bar is intended to correspond to the exposure period for a particular row. The horizontal displacement of each bar **4** is suggestive of the shifting time period during which each row of pixels is exposed. As can be seen in FIG. **2**A, the exposure period for sequential rows overlap. This is shown in more detail with respect to the timing diagrams for a rolling shutter architecture shown in FIG. **2**B. The second **12** and third **16** lines of the timing diagram represent the reset timing signal and the read out timing signal, respectively, for row "a." The fourth **20** and fifth **24** lines represent the reset and the read out timing signals, respectively for row "b." As shown in both FIGS. **2**A and **2**B, the exposure for row "b" is initiated before the values for row "a" are read out. The exposure periods for adjacent rows of pixels typically overlap substantially as several hundred rows of pixels must be exposed and read during the capture of a frame of data. As shown by the illumination timing signal on the first line **28**, the rolling shutter architecture with its overlapping exposure periods requires that the illumination source remain on during substantially all of the time required to capture a frame of data so that illumination is provided for all of the rows.

In operation, the rolling shutter architecture suffers from at least two disadvantages: image distortion and image blur. Image distortion is an artifact of the different times at which each row of pixels is exposed. The effect of image distortion is most pronounced when fast moving objects are visually recorded. The effect is demonstrated in the image shown in FIG. **3** that shows a representation of an image taken with a rolling shutter of a bus image pixels **50** passing through the field of view from right to left. As the top row of bus image pixels **54** of the bus was taken earlier than the bottom row of pixels **58**, and as the bus was traveling to the left, the bottom row of bus image pixels **58** is displaced to the left relative to the top row of bus image pixels **54**.

Image blur is an artifact of the long exposure periods typically required in a rolling shutter architecture in an image reader. As indicated above, in a rolling shutter architecture the illumination source must remain on during substantially all of the time required to capture a frame of data. Due to battery and/or illumination source limitations, the light provided during the capture of an entire frame of data is usually not adequate for short exposure times. Without a short exposure time, blur inducing effects become pronounced. Common examples of blur inducing effects include the displacement of an image sensor due to, for example, hand shake with a hand held image reader.

What is needed is an image reader that overcomes the drawbacks of current CMOS image readers including image distortion and image blur.

SUMMARY OF THE INVENTION

In one aspect, the invention features a complementary metal oxide semiconductor (CMOS) based image reader for collecting image data from a target. The CMOS based imager reader comprises a CMOS based image sensor array; a timing module in electrical communication with the CMOS based image sensor array. The timing module is capable of simultaneously exposing an entire frame of pixels of the CMOS based image sensor array during an exposure period. The CMOS based image reader also comprises an illumination module capable of illuminating the target during an illumination period. The illumination module is in electrical communication with the timing module. The CMOS based image reader further comprises a control

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module in electrical communication with the timing module and the illumination module. The control module is capable of causing at least a portion of the exposure period to occur during the illumination period. In one embodiment of the CMOS based image reader, illuminating the target comprises overdriving light sources in the illumination module. In another embodiment of the CMOS based image reader, the light sources comprise light emitting diodes. In a further embodiment of the CMOS based image reader, the exposure period starts after the start of the illumination period and the exposure period ends before the end of the illumination period. In yet another embodiment of the CMOS based image reader, the illumination period starts after the start of the exposure period and the illumination period ends before the end of the exposure period. In yet an additional embodiment of the CMOS based image reader, the illumination period starts before the start of the exposure period and the illumination period ends before the end of the exposure period. In yet a further embodiment of the CMOS based image reader, the exposure period has a duration of less than 3.7 milliseconds. In various embodiments of the CMOS based image reader, the target includes a symbology such as a one-dimensional bar code such as a Code 39 or a UPC code or a two-dimensional bar code such as a PDF417 bar code, an Aztec symbol or Datamatrix symbol.

In another aspect the invention features a complementary metal oxide semiconductor (CMOS) based image reader for collecting image data from a target. The CMOS based imager reader comprises an integrated circuit including at least a CMOS based image sensor array and global electronic shutter control circuitry. The global electronic shutter control circuitry is capable of generating an exposure control timing pulse that is capable of causing the simultaneous exposure of substantially all of an entire frame of pixels of the CMOS based image sensor array. The CMOS based image reader also comprises light sources in electrical communication with the integrated circuit. The light sources are capable of illuminating the target including the symbology in response to an illumination control timing pulse. At least a portion of the illumination control timing pulse occurs during the exposure control timing pulse. In one embodiment of the CMOS based image reader, illuminating the target comprises overdriving light sources. In another embodiment of the CMOS based image reader, the light sources comprise light emitting diodes. In a further embodiment of the CMOS based image reader, the exposure period starts after the start of the illumination period and the exposure period ends before the end of the illumination period. In yet another embodiment of the CMOS based image reader, the illumination period starts after the start of the exposure period and the illumination period ends before the end of the exposure period. In yet an additional embodiment of the CMOS based image reader, the illumination period starts before the start of the exposure period and the illumination period ends before the end of the exposure period. In yet a further embodiment of the CMOS based image reader, the exposure period has a duration of less than 3.7 milliseconds. In various embodiments of the CMOS based image reader, the target includes a symbology such as a one-dimensional bar code such as a Code 39 or a UPC code or a two-dimensional bar code such as a PDF417 bar code, an Aztec symbol or Datamatrix symbol.

In a further aspect, the invention features an image reader for collecting image data from a target. The imager reader comprises an integrated circuit including at least an image sensor array and exposure timing control circuitry. The exposure timing control circuitry is capable of generating an exposure control timing pulse that is capable of simultaneously exposing substantially all of the pixels in the image sensor array. The image reader also comprises an illumination module in electrical communication with the integrated circuit. The illumination module comprises light sources that are capable of illuminating the target in response to an illumination control timing pulse. At least a portion of the illumination control timing pulse occurs during the exposure control timing pulse. In one embodiment of the image reader, the illumination control timing pulse is generated by an illumination module. In another embodiment of the image reader, the overlap between the illumination control timing pulse and the exposure control timing pulse is coordinated by a control module that is in electrical communication with the integrated circuit and the illumination module. In a further embodiment of the image reader, the control module comprises a microprocessor. In one embodiment of the image reader, illuminating the target comprises overdriving light sources. In another embodiment of the image reader, the light sources comprise light emitting diodes. In a further embodiment of the image reader, the exposure period starts after the start of the illumination period and the exposure period ends before the end of the illumination period. In yet another embodiment of the image reader, the illumination period starts after the start of the exposure period and the illumination period ends before the end of the exposure period. In yet an additional embodiment of the image reader, the illumination period starts before the start of the exposure period and the illumination period ends before the end of the exposure period. In yet a further embodiment of the image reader, the exposure period has a duration of less than 3.7 milliseconds. In various embodiments of the CMOS based image reader, the target includes a symbology such as a one-dimensional bar code such as a Code 39 or a UPC code or a two-dimensional bar code such as a PDF417 bar code, an Aztec symbol or Datamatrix symbol.

In another aspect, the invention features a method for collecting image data from a target. The method comprises activating light sources to illuminate the target in response to an illumination control timing pulse. The activation of the light sources occurs for the duration of the illumination control timing pulse. The method also comprises simultaneously activating a plurality of pixels to photoconvert incident radiation. The activation of the plurality of pixels occurs in response to an exposure control timing pulse. The method additionally comprises storing image data collected by each of the plurality of pixels in a shielded portion of each of the plurality of pixels. The storing of the image data occurs in response to the exposure control timing pulse. The method further comprises reading out image data from the plurality of pixels wherein at least a portion of the exposure control timing pulse occurs during the illumination control timing pulse. In one embodiment, the method further comprises coordinating the overlap between the illumination control timing pulse and the exposure control timing pulse. The coordination is directed by a control module. In one such embodiment of the method, the control module comprises a microprocessor. In another embodiment of the method, illuminating the target comprises overdriving light sources in an illumination module. In an additional embodiment of the method, the light sources comprise light emitting diodes. In a further embodiment of the method, the storing of image data occurs in response to a stop portion of the exposure control timing pulse. In an additional embodiment of the method, the exposure period starts after the start of the illumination period and the exposure period ends before the

end of the illumination period. In yet another embodiment of the method, the illumination period starts after the start of the exposure period and the illumination period ends before the end of the exposure period. In yet an additional embodiment of the method, the illumination period starts before the start of the exposure period and the illumination period ends before the end of the exposure period. In yet a further embodiment of the method, the exposure period has a duration of less than 3.7 milliseconds. In various embodiments of the CMOS based image reader, the target includes a symbology such as a one-dimensional bar code such as a Code 39 or a UPC code or a two-dimensional bar code such as a PDF417 bar code, an Aztec symbol or Datamatrix symbol.

In another aspect, the invention features a bar code image reader for collecting and processing bar code data from a bar code symbol. The image reader comprises a two-dimensional array of pixels for receiving light radiation reflected from the bar code symbol, the two-dimensional array of pixels comprising a first plurality of pixels and a second plurality of pixels, the two-dimensional array capable of reading out the first plurality of pixels independently of reading out the second plurality, each of the pixels comprising a photosensitive region and an opaque shielded data storage region. The image reader also comprising an optics assembly for directing light radiation reflected from the bar code symbol onto the two-dimensional array of pixels. The image reader further comprising a global electronic shutter associated with the two-dimensional array of pixels, the global electronic shutter capable of simultaneously exposing substantially all of the pixels in the two-dimensional array. The image reader additionally comprising a processor module, the processor module in electronic communication with the two-dimensional array of pixels, the processor module capable of processing image data from the two-dimensional array of pixels to generate decoded bar code data. In one embodiment of the bar code image reader, the two-dimensional image sensor array is a complementary metal oxide (CMOS) image sensor. In another embodiment of the bar code image reader, processing the image data to generate output data comprises automatically discriminating between a plurality of bar code types.

In another aspect, the invention features a complementary metal oxide semiconductor (CMOS) based image reader for collecting image data from a target. The CMOS based imager reader comprises a CMOS based image sensor array, the CMOS based image sensor array comprising a first plurality of pixels and a second plurality of pixels, the CMOS based image sensor array capable of reading out the first plurality of pixels independently of reading out the second plurality, each of the pixels of the CMOS based image sensor array comprising a photosensitive region and an opaque shielded data storage region. The CMOS based image reader also comprising a timing module in electrical communication with the CMOS based image sensor array, the timing module configured to simultaneously expose an entire frame of pixels of the CMOS based image sensor array during an exposure period. The CMOS based image sensor array further comprising an illumination module configured to illuminate the target during an illumination period, the illumination module in electrical communication with the timing module. The CMOS based image sensor array additionally comprising a control module in electrical communication with the timing module and the illumination module, the control module configured to cause at least a portion of the exposure period to occur during the illumination period.

In a further aspect, the invention features a complementary metal oxide semiconductor (CMOS) based image reader for collecting image data from a target. The CMOS based imager reader comprising an integrated circuit including at least a CMOS based image sensor array, the CMOS based image sensor array comprising a first plurality of pixels and a second plurality of pixels, the CMOS based image sensor array capable of reading out the first plurality of pixels independently of reading out the second plurality, each of the pixels of the CMOS based image sensor array comprising a photosensitive region and an opaque shielded data storage region. The CMOS based image sensor array also comprising a global electronic shutter control circuitry, the global electronic shutter control circuitry configured to generate an exposure control timing pulse that is capable of causing the simultaneous exposure of substantially all of an entire frame of pixels of the CMOS based image sensor array. The CMOS based image sensor array further comprising light sources configured to illuminate the target in response to an illumination control timing pulse, the light sources in electrical communication with the integrated circuit. In operation of the CMOS based image reader at least a portion of the illumination control timing pulse overlaps with at least a portion of the exposure control timing pulse. In one embodiment of the CMOS based image reader, illuminating the target comprises overdriving light sources in the illumination module. In another embodiment of the CMOS based reader the light sources comprise light emitting diodes. In a further embodiment of the CMOS based image reader, the exposure control timing pulse has a shorter duration than the illumination control timing pulse. In an additional embodiment of the CMOS based image reader, the illumination control timing pulse has a shorter duration than the exposure control timing pulse. In still another embodiment of the CMOS based imager reader, the illumination control timing pulse starts before the start of the exposure control timing pulse and the illumination control timing pulse ends before the end of the exposure control timing pulse. In still a further embodiment of the CMOS based imager reader, the exposure control timing pulse has a duration of less than 3.7 milliseconds. In still an additional embodiment of the CMOS based imager reader, the target includes a symbology. In one such embodiment, the symbology is a one-dimensional bar code. In another such embodiment, the symbology is a two-dimensional bar code. In one such embodiment, the two-dimensional bar code is a PDF417 bar code.

In a further aspect, the invention features a bar code image reader for collecting image data from a bar code. The imager reader comprises an integrated circuit including at least a two-dimensional image sensor array, the two-dimensional image sensor array including a plurality of active pixels, each active pixel including at least a shielded data storage area, the two-dimensional image sensor array capable of employing a transfer function to convert an incident light intensity into an output voltage, the transfer function having a first region with a first slope and a second region with a second slope, the two-dimensional image sensor array capable of employing the second region of the transfer function when the incident light intensity is above a specified level and the two-dimensional image sensor array capable of employing the first region of the transfer function when the incident intensity is below a specified level. The bar code image reader also comprises an exposure timing control circuitry, the exposure timing control circuitry configured to generate an exposure control timing pulse that is capable of simultaneously exposing all or substantially all of

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the pixels in the image sensor array to photoconvert incident radiation. In one embodiment, the exposure control timing pulse has a duration of less than 3.7 milliseconds. In another embodiment, a dynamic range of the two-dimensional image array sensor is greater than 65 decibels.

In yet another aspect, the invention features a method for automatically focusing an image reader. The method comprises directing with an optical system light energy reflected from a target onto an image sensor. The method also comprises exposing sequentially a plurality of rows of pixels in the image sensor during a frame exposure period, the frame exposure period being defined as a time duration extending from the beginning of the exposure of the first of the plurality of rows to the end of the exposure of the last of the plurality of rows. The method further comprising varying in incremental steps an optical system from a first setting where a distinct image of objects located at a first distance from the image reader is formed on the image sensor to a second setting where a distinct image of objects located at a second distance from the image reader is formed on the image sensor. The method additionally comprising reading out a plurality of rows of image data from the plurality of rows of pixels in the image sensor, wherein the varying in incremental steps the optical system occurs during at least a portion of the frame exposure period. In one embodiment, the method further comprises analyzing the plurality of rows of image data to determine a proper setting for the optical system corresponding to a distinct image of the target being formed on the image sensor. In an additional embodiment, the method also comprises simultaneously exposing the plurality of rows in the image sensor to generate an image of the target. In one embodiment of the method, the exposure period for adjacent lines of pixels in image reader overlap. In another embodiment of the method, the target includes a symbology. In one such embodiment, the symbology is a one-dimensional bar code. In another such embodiment, the symbology is a two-dimensional bar code.

In another aspect, the invention features an image reader with an automatic focusing capability. The imager reader comprising an integrated circuit including at least an image sensor array. The image reader also comprising an optical system capable of directing light reflected from a target onto the image sensor array, the optical system having a plurality of focus settings, a first focus setting corresponding to distinct images of objects located at a first distance from the image reader being formed on the image sensor array and a second focus setting corresponding to distinct images of objects located at a second distance from the image reader being formed on the image sensor array. The image reader further comprising a rolling shutter control module configured to sequentially expose a plurality of rows of pixels in the image sensor array to collect focusing image data. The imager reader additionally comprising an automatic focusing module configured to analyze the focusing image data to determine a focus setting for the target corresponding to a distinct image of the target being formed on the image sensor, wherein the optical system is capable of being varied in incremental steps from the first focus setting to the second focus setting during at least a portion of a time period during which the rolling shutter control module is sequentially exposing the plurality of rows of pixels. In one embodiment, the imager reader further comprises a global electronic shutter control module configured to simultaneously expose the plurality of lines of pixels in the image sensor array to collect a frame of image data once the focus setting for the target has been determined. In another embodiment of the image reader, the rolling shutter control module and the global electronic shutter control module are integrated on the same integrated circuit containing the image sensor array. In a further embodiment of the image reader, the rolling shutter control module and the global electronic shutter control module are combined in a single image array control module. In an additional embodiment of the image reader, the rolling shutter control module is capable of causing exposure periods for adjacent rows of pixels to overlap.

In another aspect, the invention features an image reader for minimizing ambient light image degradation. The image reader comprises an integrated circuit including at least an image sensor array, the image sensor array providing a signal suitable for light intensity determination. The image reader also comprises a rolling shutter control module configured to sequentially expose a plurality line of pixels in the image sensor array. The image reader further comprises a global electronic shutter control module configured to simultaneously expose the plurality of lines of pixels in the image sensor array, wherein one of the rolling shutter control module and the global electronic shutter control module is capable of being selected to control the image sensor array in response to the signal suitable for light intensity determination. In one embodiment of the image reader, the signal suitable for light intensity determination includes information related to an intensity of a light source of the image reader. In another embodiment of the image reader, the signal suitable for light intensity determination is useful for determining whether a minimum integration time is satisfied. In a further embodiment of the image reader, the signal suitable for light intensity determination is useful for determining whether the exposure time (also known as the integration time) for the current environmental condition is less than a calculated minimum integration time. In yet another embodiment of the image reader, the rolling shutter control module and the global electronic shutter control module are integrated on the same integrated circuit containing the image sensor array.

In still another aspect, the invention features a method for minimizing image data degradation collected by an image reader. The method comprises determining at least one parameter related to an ambient light intensity and analyzing the at least one parameter. The method also comprises switching control of an image sensor array in the image reader from a global electronic shutter control module to a rolling shutter control module in response to the analysis of the at least one parameter. In one embodiment of the method, the at least one parameter includes an exposure time for current environmental conditions. In another embodiment of the method, the analyzing the at least one parameter includes calculating a ratio of the exposure time for current environmental conditions to a predetermined exposure time. In one such embodiment, the predetermined exposure time is based on illumination supplied by light sources of the image reader. In another embodiment of the method, analyzing the at least one parameter includes determining whether a ratio of the ambient light intensity to an intensity of a light source of the image reader exceeds a specified threshold.

The foregoing and other objects, aspects, features, and advantages of the invention will become more apparent from the following description and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the invention can be better understood with reference to the drawings described below, and the claims. The drawings are not necessarily to scale,

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emphasis instead generally being placed upon illustrating the principles of the invention. In the drawings, like numerals are used to indicate like parts throughout the various views.

FIG. **1**A is a block diagram of one embodiment of an image reader constructed in accordance with the principles of the invention;

FIG. **1**B is a schematic block diagram of an autodiscrimination module which may be utilized with the invention;

FIG. **1**C is a process for practicing principles of the invention including automatically discriminating between different dataform types;

FIG. **2**A illustrates the operation of an image sensor employing a rolling shutter architecture according to the prior art;

FIG. **2**B is a timing diagram used in the prior art rolling shutter architecture presented with respect to FIG. **2**A;

FIG. **3** is a representation of an image taken by a prior art image sensor;

FIG. **4**A is a block electrical diagram corresponding to a specific embodiment of the invention;

FIG. **4**B is a block electrical diagram corresponding to another specific embodiment of the invention;

FIG. **5**A is a block diagram of one embodiment of an illumination module in an image reader constructed in accordance with the principles of the invention;

FIG. **5**B is a block diagram of one embodiment of an image collection module in an image reader constructed in accordance with the principles of the invention;

FIG. **6** is a perspective drawing of one embodiment of a hand held image reader constructed in accordance with the principles of the invention;

FIG. **7** is a schematic block diagram of one embodiment of an image reader constructed in accordance with the principles of the invention;

FIG. **8**A is a schematic diagram of a portion of one embodiment of an image sensor array from the prior art that can be employed in one embodiment of the image reader of FIG. **7**;

FIGS. **8**B and **8**C are cross-sectional details of pixel architectures from the prior art that can be employed in one embodiment of the image reader of FIG. **7**;

FIG. **9** is a flow chart illustrating one embodiment of a process for collecting image data according to the principles of the invention;

FIGS. **10**A, **10**B, **10**C, and **10**D are timing diagrams for various embodiments of the process of FIG. **9**;

FIG. **10**E illustrates an illumination control timing pulse including a plurality of individual pulses;

FIG. **11** is a schematic diagram of a portion of an image sensor according to the prior art;

FIG. **12** is a timing diagram for the prior art image sensor of FIG. **11**;

FIG. **13** is a flow chart illustrating one embodiment of a process for automatic focusing according to the principles of the invention;

FIG. **14** is a flow chart illustrating one embodiment of a process for changing operational modes according to the principles of the invention;

FIGS. **15**A, **15**B, and **15**C are various views of one embodiment of portable data terminal image reader constructed in accordance with the principles of the invention;

FIG. **16** is an electrical block diagram of one embodiment of the portable data terminal image reader of FIGS. **15**A, **15**B, and **15**C;

FIG. **17**A shows one embodiment of a plurality of curvelent detector maps which may be utilized with the invention;

FIG. **17**B shows another embodiment of a plurality of curvelent detector maps which may be utilized with the invention;

FIG. **18** is a diagrammatic representation of a histogram analysis which may be performed in one embodiment of the invention;

FIGS. **19**A-**19**D are diagrammatic representations of an image data segmentation process according to embodiments of the invention;

FIG. **20** is a schematic block diagram of one embodiment of a lens driver constructed in accordance with the principles of the invention;

FIGS. **21**, **22**A and **22**B are diagram illustrations of a focus level detection process according to an embodiment of the invention;

FIGS. **23**, **24**, **25**, **26** and **27** are flow diagrams illustrating various focusing processes which may be practiced according to the invention;

FIGS. **28**A, **28**B and **28**C are representations of image sensor pixel array, wherein shaded regions indicate groups of positionally contiguous pixels that may be selectively addressed and read out when the image sensor array is operated in a windowed frame operating mode;

FIGS. **29**, **30**A and **30**B are diagrams illustrating a focus level detection process which may be utilized in an embodiment of the invention;

FIGS. **31** and **32** are flow diagrams illustrating additional processes which may be practiced in accordance with the invention;

FIG. **33** is an exploded assembly view of an imaging module according to the invention;

FIG. **34** is a front view of the imaging module shown in FIG. **33**;

FIG. **35** is a side view of an assembled imaging module as shown in FIG. **33**;

FIG. **36** is a view of a substrate bearing a bar code symbol and having projected thereon an illumination pattern and an aiming pattern and having delineated thereon a full frame field of view of an image reader according to the invention that projects the illumination pattern and the aiming pattern; and

FIG. **37** is a chart describing various embodiments of the invention having LEDs which emit light in different wavelength bands.

DETAILED DESCRIPTION OF THE INVENTION

The invention features an image reader and a corresponding method for capturing a sharp non-distorted image of a target. In one embodiment, the image reader comprises a two-dimensional CMOS based image sensor array, a timing module, an illumination module, and a control module all in electrical communication with each other. The illumination module shines light on the target, such as a symbology such as one or two-dimensional bar code, so that reflected light that can be collected and processed by the image sensor array. The time during which the target is illuminated is referred to as the illumination period. The capture of the image by the image sensor array is driven by the timing module that, in one embodiment, is able to simultaneously expose all or substantially all of the pixels in the array. The simultaneous exposure of the pixels in the sensor array enables the image reader to capture a distortion free image.

The time during which the pixels are collectively activated to photo-convert incident light into charge defines the exposure period for the sensor array. At the end of the exposure period, the collected charge is transferred to a shielded storage area until the data is read out. In one embodiment, the exposure period and the illumination period are under the control of the control module. In one such embodiment, the control module causes at least a portion of the exposure period to occur during the illumination period. By adequately shortening either the illumination period or the exposure period in an environment of low ambient lighting or the exposure period in an environment of high ambient lighting, the image reader of the present invention is able to capture an image substantially free of blurring.

Referring to FIG. **1**A, a block diagram of a general image reader **100** constructed in accordance with the invention is shown. The general image reader includes one or more of: an illumination module **104**, an image collection module **108**, a control module **112**, a memory module **116**, an I/O module **120**, an actuation module **124**, a user feedback module **128**, a display module **132**, a user interface module **134**, a radio frequency identification (RFID) module **136**, a smart card module **140**, magnetic stripe card module **144**, a decoder module **150**, an autodiscriminating module **152**, and/or one or more power modules **168** and a lens driver module **165**. In various embodiments each of the modules is in combination with one or more of the other modules. In one embodiment, the image reader **100** comprises a bar code image reader with a full frame electronic global shutter based image sensor that is capable of simultaneously exposing substantially all of the pixels in the image sensor. In one such embodiment, the image sensor is a CMOS based image sensor. In another such embodiment, the image sensor is a CCD based image sensor.

Dataform decode module **150** (which may be a bar code symbol dataform decode module) when receiving image data transferred by control module **112** may search the image data for markers, such as a quiet zone, indicative of the presence of a dataform, such as a one or two-dimensional bar code. If a potential dataform is located, the dataform decode module **150** applies one or more dataform decoding algorithms to the image data. If the decode attempt is successful, the image reader outputs decoded dataform data through I/O module **120** and signals a successful read with an alert, such as a beep tone through user interface module **134**.

Image reader **100** may also include an autodiscriminating module **152**. Referring to FIG. **1**B, autodiscriminating module **152** may incorporate a dataform decode module **150** and an image processing and analysis module **1208**, that are in communication with one another.

As shown in this embodiment, the image processing and analysis module **1208** comprises a feature extraction module **1212**, a generalized classifier module **1216**, a signature data processing module **1218**, an OCR decode module **1222**, and a graphics analysis module **1224** that are in communication with each other. In addition as shown in FIG. **1**B, the feature extraction module **1212** comprises a binarizer module **1226**, a line thinning module **1228**, and a convolution module **1230** that are in communication with each other.

FIG. **1**C shows a process **1300** for employing one embodiment of the invention utilizing the autodiscrimination module shown in FIG. **1**B. The process **1300** comprises an image reader recording an actuation event (step **1302**), such as a trigger pull as sensed by actuation module **124**, and in response collecting (step **1304**) image data from a target with the image reader **100**. The collecting of image data step may be in accordance with e.g., process **300**, process **400**, (this process is used twice, see FIG. **13** and FIGS. **23** and **24**), process **600** or process **800**. After collection, the image data is transferred (step **1308**) to the dataform decode module **150**. The dataform decode module searches (step **1310**) the image data for markers, such as a quiet zone, indicative of the presence of a dataform, such as a one or two-dimensional bar code. If a potential dataform is located, the dataform decode module **150** applies (step **1314**) one or more dataform decoding algorithms to the ensuing image data. If the decode attempt is successful, the image reader **100** outputs (step **1318**) decoded dataform data and signals (step **1322**) a successful read with an alert, such as a beep tone.

In one embodiment if the decode attempt is not successful, the image data is transferred (step **1326**) to the image processing and analysis module **1208**. In another embodiment, the image data is processed in parallel with the attempt to decode the dataform data. In one such embodiment, the process that completes first (i.e., dataform decode attempt or the image processing) outputs its data (e.g., a decoded bar code or a captured signature) and the other parallel process is terminated. In a further embodiment, the image data is processed in response to the decoding of the dataform. In one such embodiment, a bar code encodes item information such as shipping label number and information indicating that a signature should be captured.

Within the image processing and analysis module **1208**, the image data is processed by the feature extraction module **1212**. In general, the feature extraction module generates numeric outputs that are indicative of the texture of the image data. As indicated above, the texture of the image data refers to the characteristics of the type of data contained in the image data. Common types of texture include one or two-dimensional bar code texture, signature texture, graphics texture, typed text texture, hand-written text texture, drawing or image texture, photograph texture, and the like. Within any category of textures, sub-categories of texture are sometime capable of being identified.

As part of the processing of the image data by the feature extraction module **1212**, the image data is processed (step **1328**) by the binarizer module **1226**. The binarizer module **1226** binarizes the grey level image into a binary image according to the local thresholding and target image size normalization. With the image data binarized, the image data is processed (step **1332**) by the line thinning module **1228** to reduce multi-pixel thick line segments into single pixel thick lines. With binarized line thinned image data, the image data is processed (step **1336**) by the convolution module **1230**.

In general, the convolution module **1230** convolves the processed image data with one or more detector maps designed according to the invention to identify various textural features in the image data. In one embodiment, the convolution module **1230** generates a pair of numbers, the mean and variance (or standard deviation), for each convolved detector map. FIG. **17**A shows a set of 12 2×3 binary curvelet detector maps **1250** used to detect curved elements present in image data. As each of the curvelet detector maps **1250** is convolved with the image data, the mean value and the variance generated provide an indication of the presence or density of elements in the binarized line thinned image data having similar shapes to the curvelet detector maps **1250**. As each pixel map generates a pair of numbers, the 12 curvelet detector maps **1250** generate a total of 24 numbers. According to one embodiment, these 24 numbers are representative of the curved or signature texture of the processed image data.

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Further processing of the image data includes the outputs from the feature extraction module **1212** being fed (step **1340**) into the generalized classified module **1216**. The generalized classifier module **1216** uses the numbers generated by the feature extraction module as inputs to a neural network, a mean square error classifier or the like. These tools are used to classify the image data into general categories. In embodiments employing neural networks, different neural network configurations are contemplated in accordance with the invention to achieve different operational optimizations and characteristics. In one embodiment employing a neural network, the generalized classifier module **1212** includes a 24+12+6+1=43 nodes Feedforward, Back Propagation Multilayer neural network. The input layer has 24 nodes for the 12 pairs of mean and variance outputs generated by a convolution module **1230** employing the 12 curvelet detector maps **1250**. In the neural network of this embodiment, there are two hidden layers of 12 nodes and 6 nodes respectively. There is also one output node to report the positive or negative existence of a signature.

In another embodiment employing a neural network, the 20 curvelet detector maps **1260** shown in FIG. **17**B are used by the convolution module **1230**. As shown, the 20 curvelet detector maps **1260** include the original 12 curvelet detector maps **1250** of FIG. **17**A. The additional 8 pixel maps **1260** are used to provide orientation information regarding the signature. In one embodiment employing the 20 curvelet detector maps **1260**, the generalized classifier module **216** is a 40+40+20+9=109 nodes Feedforward, Back Propagation Multiplayer neural network. The input layer has 40 nodes for the 20 pairs of mean and variance outputs generated by a convolution module **1230** employing the 20 curvelet detector maps **1260**. In the neural network of this embodiment, there are two hidden layers of 40 nodes and 20 nodes respectively, one output node to report the positive or negative existence of a signature, and 8 output nodes to report the degree of orientation of the signature. The eight output nodes provide $2^8=256$ possible orientation states. Therefore, the orientation angle is given in degrees between 0 and 360 in increments of 1.4 degrees.

In some embodiments, the generalized classifier module **1216** is capable of classifying data into an expanded collection of categories. For example in some embodiments, the generalized classifier module **1216** specifies whether the image data contains various data types such as a signature; a dataform; handwritten text; typed text; machine readable text; OCR data; graphics; pictures; images; forms such as shipping manifest, bill of lading, ID cards, and the like; fingerprints, biometrics such as fingerprints, facial images, retinal scans and the like, and/or other types of identifiers. In further additional embodiments, the generalized classifier module **1216** specifies whether the image data includes various combinations of these data types. In some embodiments, the general classifier module **1216** specifies whether the image data contains a specified type of data or not. In one such embodiment, the image processing and analysis module **1208** is contained within an identification module that outputs an affirmative or negative response depending on the presence or absence of the specified data type, such as a signature or a biometric, in the image data.

In one embodiment once the presence of a signature has been confirmed and its general orientation determined, image data is transferred (step **1344**) to the signature data processing module **1218**. In one embodiment, the signature data processing module **1218** is used to detect the boundaries of the signature in the image data. In one embodiment, the signature boundary is detected using a histogram analysis. As shown in FIG. **18**, a histogram analysis consists of a series of one-dimensional slices along horizontal and vertical directions defined relative to the orientation of the signature. In one embodiment, the value for each one-dimensional slice corresponds to the number of black (i.e., zero valued) pixels along that pixel slice. In some embodiments if no bar codes have been decoded, then some specified region of the full frame of image data, such as a central region is captured for signature analysis. Once completed, the histogram analysis provides a two-dimensional plot of the density of data element pixels in the image data. The boundary of the signature is determined with respect to a minimum density that must be achieved for a certain number of sequential slices. In one embodiment, the histogram analysis searches inwardly along both horizontal and vertical directions until the pixel density rises above a predefined cutoff threshold. So that the signature data is not inadvertently cropped, it is common to use low cutoff threshold values.

In one embodiment, once the boundaries of the signature have been determined, the signature data processing module **1218** crops the image data and extracts the signature image data. In one such embodiment, the cropping is performed by an image modification module that generates modified image data in which a portion of the image data not including the signature has been deleted. In other embodiments, various compression techniques are employed to reduce the memory requirements for the signature image data. One such technique includes the encoding of the signature image data by run length encoding. According to this technique, the length of each run of similar binarized values (i.e., the length of each run of 1 or 0) for each scan line is recorded as a means of reconstructing a bit map. Another encoding technique treats the signature image data as a data structure where the elements of the data structure consist of vectors. According this encoding technique, the signature is broken down into a collection of vectors. The position of each vector in combination with the length and orientation of each vector is used to reconstruct the original signature. In one such embodiment, the encoding process generates a new vector whenever the curvature for a continuous pixel run exceeds a specified value. A further compression technique employs B-Spline curve fitting. This technique has the capacity to robustly accommodate curvature and scaling issues.

In various embodiments, the signature image data or a compressed or encoded version of the signature image data is stored locally on a dedicated memory device. In one such embodiment, the local memory device can be a detachable memory device such as a CompactFlash memory card or the like described in more detail below. In another embodiment, the signature image data is stored in a volatile or non-volatile portion of general purpose memory and downloaded at a future time. In a further embodiment, the signature image data can be transmitted via wired or wireless means either at the time of capture or at a later point, such as when a data collection session has been completed.

In another embodiment, the signature data processing module **218** does not perform a histogram analysis but simply stores in memory the entire image or a compressed version once the presence of a signature has been determined. In a further embodiment to save processing time, the initial image analysis is performed on a lower resolution image. Once the presence of a signature is determined in this embodiment, a higher resolution image is taken. In one embodiment, a signature extraction histogram analysis is performed on this image. Next, the image is stored in

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memory in either compressed or original format. In some embodiments, the image data is combined with other data to form a record for a particular item such as a package or shipping envelope. As mentioned above, some of the additional data that can be collected by the image reader **100** and stored with or separate from the signature data includes but is not limited to dataform data, handwritten text data, typed text data, graphics data, image or picture data, and the like.

As part of its operations, the image processing and analysis module **1208** can be designed to perform specialized tasks for different data types. For example, if the generalized classifier module **1216** determines that the image data contains typed or machine readable text, the image data can be collected, possibly histogram analyzed, and stored or alternatively the image data can be transferred to the OCR decoding module **1222**. Similarly, if the generalized classifier module **1216** determines that the image data includes a graphic element, the image data can be transferred to the graphics analysis module **1224** for processing. In one embodiment, the graphics analysis module **1224** is configured to recognize and decode predefined graphics. In one such embodiment, the graphics analysis can include determining which, if any, boxes have been selected in the billing and shipping instructions on a shipping label. In a further embodiment, the graphics analysis can include locating and decoding the typed or handwritten text contained in the zip code box on a shipping label. In an alternative embodiment, the image reader **100** can be configured to automatically attempt decode operations in addition to the dataform decode, such as OCR decoding or graphics decoding, prior to the activation of the feature extraction module **1212**.

In another embodiment, the image processing and analysis module **1208** segments the image data into regions and performs a feature extraction and general classification analysis on each region. In one embodiment as shown in FIG. **19**A, the standard rectangular image data window is divided into four equal sized sub-rectangles. In another embodiment shown in FIG. **19**B, the segmentation consists of overlapping regions so that the total area of the segmented regions is larger than that of the complete field of the image data. In FIG. **8**B there are seven shown overlapping regions where each identifying numeral is shown in the center of its region. In a further embodiment shown in FIGS. **19**C and **19**D, the segmentation consists of sample regions (shown as cross-hatched) within the complete field of the image data. In another embodiment, the sampled regions can be based on a preloaded user template that, for example, identifies regions of interest such as a signature region and/or a bar code region, in for example, a shipping label.

In one embodiment, the segmentation process is used to identify the location of a signature in image data the might include additional elements such as dataforms including bar code dataforms, text, graphics, images and the like. In one such embodiment the generalized classifier module **1216** classifies the contents of each region of the segmented image data. The region containing the signature is then extracted by the signature data processing module **1218**. In one embodiment if multiple regions are indicated as containing signature data, the signature data processing module **1218** analyzes the arrangement of these regions to identify the region most likely to contain the image data. In a further embodiment when multiple regions are indicated as containing signature data, the image processing and analysis module establishes a feedback loop where additional segmented regions are generated and analyzed until a single segmented region containing signature data is located.

Additional image processing operations which may be carried out by image reader **100** are described in U.S. patent application Ser. No. 10/958,779, filed Oct. 5, 2004 entitled, “System And Method To Automatically Discriminate Between A Signature And A Bar code” and incorporated herein by reference in its entirety.

Referring to additional components of image reader **100** indicated in FIG. **1**A and FIG. **5**A, illumination module **104** can include light sources **160**, an illumination control module **164**, an illumination power module **168***a*, and an interface module **172**. In various embodiments, the light sources **160** can include white or colored LEDs, such as 660 nm illumination LEDs, infrared LED, ultra-violet LED, lasers, halogen lights, arc lamps, or incandescent lights, capable of producing adequate intensity light given image reader power constraints and image sensor exposure/sensitivity requirements. In many embodiments, LEDs are chosen for the light source as their efficient operation enables relatively low power consumption. The illumination control module **164** controls the operation of illumination module **104** and can include timing and light source activation and deactivation circuitry. The illumination power module **168***a* supplies the energy necessary to drive the light sources **160** and can include batteries, capacitors, inductors, transformers, semiconductors, integrated circuits and the like. In an alternative embodiment, some or all of the elements of the illumination power module **168***a* are located external to the illumination module. An image reader **100** with a single common power source is one such embodiment. The interface module **172** is used for communication with the other modules of the image reader **100** such as those required to synchronize operations. This can include, for example, the coordination of the illumination and exposure periods discussed above.

Referring to the physical form views of FIGS. **33**-**36**, various components of illumination module **104** and image collection module **108** according to one embodiment of the invention are shown and described. An image reader **100** of the invention, as shown in the embodiment of FIGS. **15**A-**15**C, may include an imaging module such as imaging module **1802**. Imaging module **1802** as shown in FIGS. **33**-**35** incorporates certain features of an IT4000 imaging module as referenced herein and additional features. Imaging module **1802** includes first circuit board **1804** carrying light sources **160***a*, **160***b*, while second circuit board **1806** carries light sources **160***c*, **160***d*, **160***e*, **160***f*, **160***g*, **160***h*, **160***i*, **160***j*, **160***k*, **160***l*, **160***m*, **160***n*, **160***o*, **160***p*, **160***q*, **160***r*, **160***s*, and **160***t* (hereinafter **160***c* through **160***t*). First circuit board **1804** also carries image sensor array **182**. Imaging module **1802** also includes support assembly **1810** including lens holder **1812**, which holds lens barrel **1814** that carries imaging lens **212**. Light sources **160***a*, **160***b* are aiming illumination light sources whereas light sources **160***c* through **160***t* are illumination light sources. Referring to FIG. **36**, illumination light sources **160***c* through **160***t* project a two-dimensional illumination pattern **1830** over a substrate, s, that carries a decodable indicia such as a bar code symbol **1835** whereas aiming illumination light sources **160***a*, **160***b* project an aiming pattern **1838**. In the embodiments shown and described in connection with FIGS. **33**-**36**, light from aiming illumination light sources **160***a*, **160***b* is shaped by slit apertures **1840** in combination with lenses **1842** which image slits **1840** onto substrate, s, to form aiming pattern **1838** which in the embodiment of FIGS. **33**-**36** is a line pattern **1838**. Illumination pattern **1830** substantially corresponds to a full frame field of view of image reader **100** designated by box **1850**. Aiming pattern **1838** is in the form of a line that extends horizontally across

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a center of field of view of image reader **100**. Illumination pattern **1830** may be projected when all of illumination light sources **160***c* through **160***t* are operated simultaneously. Illumination pattern **1830** may also be projected when a subset of light sources **160***c* through **160***t* are simultaneously energized. Illumination pattern **1830** may also be projected when only one of light sources **160***c* through **160***t* is energized such as LED **160***s* or LED **160***t*. LEDs **160***s* and **160***t* of imaging module **1802** have a wider projection angle than LEDs **160***c* through **160***t*.

As shown in FIG. **5**B, the image collection module **108** in one embodiment includes an optics module **178**, a sensor array module **182**, and a sensor array control module **186** all in electrical communication with each other. The optics module **178** includes an imaging lens or other optical elements used to direct and focus reflected radiation. In some embodiments, the optics module **178** includes associated circuitry and processing capacity that can be used, for example, as part of automatically determining the proper focus for an object, being imaged.

The sensor array control module **186** includes a global electronic shutter control module **190**, a row and column address and decode module **194**, and a read out module **198**, each of which modules is in electrical communication with one or more of the other modules in the sensor array control module **186**. In one embodiment, the sensor array module **182** includes components of an integrated circuit chip **1082** as shown in FIG. **4**A with a two-dimensional CMOS based image sensor array **182**. In various embodiments, associated circuitry such as analog-to-digital converters and the like can be discrete from the image sensor array or integrated on the same chip as the image sensor array. In an alternative embodiment, the sensor array module **182** can include a CCD sensor array capable of simultaneous exposure and storage of a full frame of image data. As indicated above in one embodiment, the global electronic shutter control module **190** is capable of globally and simultaneously exposing all or substantially all of the pixels in the image sensor array. In one embodiment, the global electronic shutter control module **190** includes a timing module. The row and column address and decode module **194** is used to select particular pixels for various operations such as collection activation, electronic shutter data storage and data read out. The read out module **198** organizes and processes the reading out of data from the sensor array. In some embodiments, the sensor array control module **186** further includes a rolling shutter control module **202** that is capable of sequentially exposing and reading out the lines of pixels in the image sensor array.

A specific embodiment of image reader **100** is described with reference to FIG. **4**A. In the embodiment of FIG. **4**A and image sensor array **182**, **182***a* having a two-dimensional array of pixels **250** is incorporated onto CMOS integrated circuit (IC) chip **1082**, **1082***a*. As is described later with reference to FIG. **8**A, image sensor array **182***a* is a CMOS image sensor array adapted to operate in a global shutter operating mode. Each pixel **250** of CMOS image sensor array **182***a* has an on-chip pixel amplifier **254** (shown in FIG. **8**A) and an on-chip optically shielded storage area **286** (shown in FIG. **8**B and FIG. **8**C). Image sensor array **182***a* may also have a two-dimensional grid of electrical interconnects **262** as shown in FIG. **8**A that are in electrical communication with pixels **250**. Image sensor array **182***a* may also have an on-chip row circuitry **296** and column circuitry **270**. Row circuitry **296** and the column circuitry **270** may enable one or more various processing and operational tasks such as addressing pixels, decoding signals, amplification of signals, analog-to-digital signal conversion, applying timing, read out and reset signals and the like. Referring to further aspects of CMOS image sensor IC chip **182***a*, CMOS image sensor IC chip **182***a* includes, on the same chip as pixels **250** row circuitry **296**, column circuitry **270**, processing and control circuitry **254** including pixel amplifiers **255**, optically shields storage area **258**, interconnects **262**, a gain circuit **1084**, an analog-to-digital conversion circuit **1086** and line driver circuit **1090**, which generates a multi-bit (e.g., 8 bit 10 bit) signal indicative of light incident on each pixel **250** of array, the output being presented on a set of output pins of chip **1082***a*. Referring to additional on-chip elements of image sensor IC chip **1082***a*, CMOS image sensor IC chip **1082***a* includes timing/control circuit **1092** which may include such components as a bias circuit, a clock/timing generation circuit, and an oscillator. Timing/control circuit **1092** may form part of sensor array control module **108** as described in connection with FIG. **5**B.

Referring to further aspects of image reader **100** of FIG. **4**A, image reader **100** includes a main processor IC chip **548**, memory module **116**, illumination module **104**, and actuation module **124**. Main processor IC chip **548** may be a multifunctional IC chip having an integrated frame grabber circuit **549** and central processing unit (CPU) **552**. Processor IC chip **548** with an integrated frame grabber may be an e.g., an XSCALE PXA27X processor IC chip with “Quick Capture Camera Interface” available from INTEL. Image reader **100** further includes actuation module **124** which generates a trigger signal that initiates a bar code decode process. Actuation module **124** may include a manually actuated trigger **216**. Image reader **100** further includes imaging lens **212** and memory module **116** including such memory devices as a RAM, EPROM, flash memory. Memory module **116** is in communication with processor IC chip **548** via a system bus **584**. Processor IC chip **548** may be programmed or otherwise configured to carry out various functions required of modules **104**, **108**, **112**, **120**, **124**, **128**, **132**, **134**, **136**, **140**, **144**, **150**, **152**, **168**, **165** described with reference to FIG. **1**A. In the embodiment of FIG. **4**A, the functions of dataform decode module **150** and autodiscrimination module **152** are carried by processor IC chip **548** operating in accordance with specific software stored in memory module **116**. The combination of processor IC chip **548** and memory module **116** is, therefore, labeled **150**, **152** in the embodiment of FIG. **4**A.

Referring to FIG. **4**B, an embodiment of image reader **100** is shown which has a CCD image sensor chip **1082**, **1082***b*. CCD image sensor IC chip **1082***b*. CCD image sensor IC chip **1082***b* includes an area array of pixels **250**, a register **1094** and an output amplifier **1096** incorporated onto chip **1082***b*. Output register **1094** and associated circuitry sequentially converts the charge associated with each pixel into a voltage and sends pixel image signals to a component external to chip **1082***b*. When actuated to read out image data, charges on a first row of pixels **250** are sequentially transferred to output register **1094**. Output register **1094** sequentially feeds charges to amplifier **1096** which converts pixel charges into voltages and supplies signals to image processing circuitry **1070**. When charges are transferred from a first row of pixels to output register **1094**, charges from a next row move down one row so that when a first row of charges has been converted into voltages, output register **1094** receives charges from a second row of pixels. The process continues until image data corresponding to pixels from all of the rows of image sensor array **182***b* are read out. Image reader **100** further includes image signal processing circuit **1070** external to chip **1082***b*. Image signal processing

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circuit **1070** includes such elements as a gain circuit **1072** an analog-to-digital converter **1074** and a line driver **1076**. Timing and control circuit **1078** of circuit **1070** may include such elements as a bias generator, an oscillator, a clock and timing generator. The gain circuit **1072** may also implement additional functionality such as correlated double sampling to reduce to effects of pixel offsets and noise. Additional components of image reader **100** are as shown in FIG. **4**A. Image signal processing circuit **1070** may be included in an integrated circuit chip (IC chip) external to image sensor IC chip **1082***b*.

In one embodiment, components of image collection module **108** and illumination module **104** are provided by any one of the IMAGETEAM™ area (2D) imaging engines, such as the 4000 OEM 2D Image Engine available from Hand Held Products, Inc. of 700 Visions Drive, P.O. Box 208, Skaneateles Falls, N.Y., constructed in accordance with the principles of the invention.

Referring to FIG. **6**, a perspective drawing of a hand held image reader **100***a* constructed in accordance with one embodiment of the invention is shown. The hand held image reader **100***a* includes a housing **208**, a plurality of light sources **160**, a lens **212**, a trigger **216**, and an interface cable **200**. In various embodiments, the functionality of the image reader **100***a* can be provided by any one of the area (2D) IMAGETEAM™ image readers such as the models **4410**, **4600**, or **4800** available from Hand Held Products, Inc. and constructed in accordance with the invention. All of the modules **104**, **108**, **112**, **116**, **120**, **124**, **128**, **132**, **134**, **136**, **140**, **144**, **150**, **152**, **165**, and **168** described in connection with FIG. **1**A may be incorporated into, and may be supported by hand held housing **208** or alternative housing **506** shown in FIG. **15**A such that housing **208** or housing **506** encapsulate and support the various modules. Likewise, all of the components shown in FIGS. **4**A and **4**B and FIG. **16** may be incorporated into and may be supported by housing **208** or housing **506** such that housing **208** or housing **506** encapsulate and support the various components. Lens **212** may comprise glass and/or polycarbonate. Lens **212** may be a lens singlet or else comprise a plurality of lens components; that is, lens **212** may be a lens doublet or lens triplet, etc.

Referring to FIG. **7**, a diagrammatic cross sectional view in combination with a schematic block diagram for the image reader **100** is shown. The image reader **100** includes the light sources **160**, an illumination control module **164**, a power module **168***b*, and an interface module **172** all in electrical communication with each other. The light sources **160** direct light energy **162** towards a target **166** including a symbology **170**. Reflected radiation **174** from the target **166** is focused by a lens **212** onto an image sensor array **182** in electrical communication with a sensor array control module **186** and the power module **168***b*. In one embodiment, the image sensor array **182** is a CMOS based image sensor array. In another embodiment, the image sensor array **182** is a CCD based image sensor array. The sensor array control module **186** is further in electrical communication with a memory module **116** and a control module **112** also in electrical communication with the power module **168***b* and the interface module **172**. Often an optical window (not shown) is placed on the front of the scanner to reduce the likelihood of damage to the unit.

Referring to FIG. **8**A, a diagram of a portion of a CMOS based image sensor array **182***a* is shown in more detail. The image sensor array **182***a* includes a two-dimensional array of pixels **250**. Each pixel includes a photosensitive sensitive region **252**, processing and control circuitry **254** including amplifier **255** and a shielded storage area **258** (for clarity of presentation, the reference numerals **252**, **254**, **255**, and **258** are provided only with respect to a single pixel). The presence of amplifier **255** means that the CMOS image array **182***a* is considered an active pixel array; that is, each pixel of the CMOS image array **182***a* is able to amplify the signal generated from the photo-conversion of incident light energy. The charge-to-voltage conversion circuitry allows the CMOS image array **182***a* to convert the collected charge into an output signal. The shielded storage area **258** stores collected pixel values until read out so that additional incident radiation impinging on the CMOS image array **182***a* does not corrupt the value read during the defined exposure period. In addition to pixel amplifier **255**, the processing and control circuitry **254** for each pixel **250** may include, among other elements, a reset and select transistor.

In one embodiment, the dynamic range of the CMOS based image sensor array **182***a* is extended by providing additional intelligence in the processing and control circuitry **254**. In particular, the processing circuitry is augmented to include the capacity to dynamically change the conversion factor between the incident radiation input intensity and the output voltage. That is, the processing circuitry employs a transfer curve with multiple slopes. The particular form of the transfer curve with its multiple slopes can take various forms including a series of linear relations joined at knee points, a linear section at low intensity connected to a logarithmic transfer curve at higher intensity, or a completely continuous curve of arbitrary shape with steeper slopes for low intensity and higher slopes at greater intensities.

In the multiple slope embodiment, the dynamic range of the CMOS based image sensor **182***a* is significantly extended as each individual pixel is capable of independently employing a different section of the transfer curve depending on the intensity of radiation incident upon it. In operation, regions of the CMOS based image sensor **182***a* that are receiving less incident radiation employ a steeper conversion slope corresponding to greater sensitivity and regions that are receiving more incident radiation employ a shallower conversion slope corresponding to less sensitivity. With a multiple slope transfer function, the CMOS based image sensor **182***a* can achieve a dynamic range of 65 to 120 dB. The operation of image sensors with transfer curves with multiple slopes are described in more detail in the technical document entitled "Dual Slope Dynamic Range Expansion" from FillFactory Nev., Schaliënhoevedreef 20B, B-2800 Mechelen, Belgium. This document is available from the Fill Factory (www.fillfactory.com), for example at http://www.fillfactory.com/htm/technology/htm/dual-slope.htm and is hereby herein incorporated in its entirety. The operation of image sensors with transfer curves with logarithmic slopes are described in more detail in the technical document entitled "LinLog Technology" from Photonfocus AG, Bahnhofplatz 10, CH-8853 Lachen, Switzerland. This document is available from the Photonfocus (www.photonfocus.com), for example at http://www.photonfocus.com/html/eng/cmos/linlog.php and is hereby herein incorporated in its entirety.

Overlaying the pixels **250** in FIG. **8**A is a two-dimensional grid of electrical interconnects **262** that are in electrical communication with the pixels **250**, the row circuitry **296** (see also FIG. **4**A) and the column circuitry **270**. The row circuitry **296** and the column circuitry **270** enable one or more processing and operational tasks such as addressing pixels, decoding signals, amplification of signals, analog-to-digital signal conversion, applying timing, read out and

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reset signals and the like. With on-chip row circuitry **296** and column circuitry **270**, CMOS based image sensor array **182***a* may be operated to selectively address and read out data from individual pixels in an X-Y coordinate system. CMOS based image sensor array **182***a* may also be operated by way of appropriate programming of image reader **100**, to selectively address and read out a portion of the full frame of pixels. For example, in these embodiments the portion of pixels read out can exclude undesired pixels external to a desired pixel region. The portion of pixels read can also represent a sampling of pixels in a region so that individual pixels, rows of pixels, or columns of pixels in the region of interest are not read out. Further details of image reader **100** operating in a windowed frame operating mode in which image reader **100** selectively addresses and reads out image data from less than all pixels of image sensor array **182** is described in connection with FIGS. **28**A, **28**B, and **28**C. In general, image reader **100** can be programmed or otherwise configured to selectively address and read out from CMOS based image sensor array **182***a* image data from a first plurality of pixels in the array independently of selectively addressing and reading out a second plurality of pixels in the array.

In one embodiment, the pixel architecture can be as described in U.S. Pat. No. 5,986,297 assigned to Eastman Kodak Company and entitled "Color Active Pixel Sensor with Electronic Shuttering, Anti-blooming and Low Crosstalk." In particular at column 3 lines 35 to 55 and at column 5 lines 25 to 55, the patent describes the cross sections of the relevant regions of the pixel architectures shown in the patent's FIGS. **1**A and **2**A (herein reproduced as FIGS. **8**B and **8**C). The disclosure states that the pixel in FIG. **8**B comprises a photodiode **270** with a vertical overflow drain **274**, transfer gate **276**, floating diffusion **280**, reset gate **282**, reset drain **284**, and a light shield **286**. A light shield aperture **288**, color filter **290**, and micro lens **292** are placed over the photodetector such that light is focused through micro lens **292** into light shield aperture **288** after passing through color filter **290**. Therefore, the light entering photodiode **270** has a wavelength that is within a predetermined bandwidth as determined by the color filter **290**. The patent describes FIG. **8**C as showing a second pixel architecture that is similar in many respects to the embodiment shown in FIG. **8**B except that there are two transfer gates **294**, **296**, and a storage region **298**. In both cases the light shield is constructed by effectively covering all regions except the photodetectors (photodiode **270** in this case), with an opaque layer or overlapping layers, so that incident light falls only on the photodiode area. Creation of an aperture in a light shield that limits the creation of photoelectrons to the photodetector region suppresses cross-talk between pixels. In FIG. **8**C, the floating diffusion is labeled **281**, the reset gate is labeled **283**, and the reset drain is labeled **285**. In some embodiments employing the pixel architecture described in U.S. Pat. No. 5,986,297, the color filter **290** may be omitted, and in other embodiments the microlens **292** may be omitted.

A process **300** for collecting image data from a target with the image reader **100** is presented with respect to FIGS. **9**, **10**A, **10**B, **10**C and **10**D. In various embodiments the target can contain a symbology such as a one or two-dimensional bar code. At step **302**, actuation module **124** initiates process **300** in response e.g., to trigger **216** being depressed or to a sensing of a presence of an object in a field of view of image reader **100**. In one embodiment, control module **112** may receive a trigger signal in response to a depressing of trigger **216** or the sensing of an object and responsively present a series of control signals to various modules, e.g., illumination module **104** and image collection module **108** in accordance with process **300**. The process **300** includes activating (step **304**) an illumination source to illuminate the target with illumination light **162**. In one embodiment, the activation of the illumination source occurs in response to an illumination control timing pulse **350**. The illumination of the target by the activated illumination source occurs for the duration of the illumination control timing pulse **350**. In one embodiment, the illumination source is the light source **160** and the illumination control timing pulse **350** is generated by the illumination control module **164** in the illumination module **104**. The process **300** also includes activating the global electronic shutter to simultaneously expose (step **312**) a plurality of pixels in a plurality of rows in an image sensor array to photoconvert incident radiation into electric charge. The simultaneous activation of the plurality of pixels occurs in response to an exposure control timing pulse **354**. In one embodiment, the simultaneous activation of the plurality of pixels occurs in response to a start portion **360** of the exposure control timing pulse **354**. In a further embodiment, the exposure control timing pulse **354** is generated by the global electronic shutter control module **190** (FIG. **5**B) of the sensor array control module **186**.

In one embodiment for collecting an image of a target that minimizes translational image distortion, the target is illuminated by overdriving the illumination sources, such as LEDs, to generate illumination several times brighter than standard operation. Referring to an example of the invention wherein image reader **100** includes imaging module **1802** as shown in FIGS. **33-35**, LEDs **160***c* through **160***t* (that is, **160***c*, **160***d*, **160***e*, **160***f*, **160***g*, **160***h*, **160***i*, **160***j*, **160***k*, **160***l*, **160***m*, **160***n*, **160***o*, **160***p*, **160***q*, **160***r*, **160***s*, and **160***t*) each may have a standard recommend maximum DC operation current draw rating of 40 mA (100% LED current) but may be overdriven to draw more than e.g., 60 mA (150% current), or 80 mA (200% current) throughout the duration of illumination timing pulse **350**, or any one of pulses **350'**, **350"**, **350'"** described herein. LEDs **160***c* through **160***t*, where LEDs **160***c* through **160***t* have a standard recommended maximum DC operating current draw rating of 40 mA, may also be overdriven to draw more than e.g., 120 mA (300% current), 160 mA (400% current), 200 mA (500% current), or 500 mA (1,250% current) throughout the duration of timing pulse **350** or any one of pulses **350'**, **350"**, **350'"** described herein. Illumination timing pulse **350**, **350'**, **350"**, **350'"** are shown as DC drive current pulses. However, according to the invention as indicated by FIG. **10**E, pulses **350**, **350'**, **350"**, **350'"** can also be pulse modulated or "strobed" pulses such that each pulse **350**, **350'**, **350"**, **350'"** comprise a series of short duration individual pulses for driving LEDs **160**. Substituting a pulsed driving signal for a DC driving signal reduces the duty cycle of LEDs, and thus the power dissipated in the LEDs. Since in many cases the LED operating life is determined by the maximum junction temperature of the LED die, reduced power dissipation reduces the junction temperature. The net effect is that a higher peak current can be tolerated while not exceeding the maximum operating junction temperature limit for the LED die. In general, reducing the duty cycle of LEDs **160** increases the amount of current that can be safely driven through LEDs. The strobing rate of a "strobed" or "pulsed" illumination control pulses as described herein may be, e.g., 1,000 Hz to 10,000 Hz. According to this embodiment, the overdriven illumination sources in combination with the electronic global shutter allows for short exposure periods. That is, the bright illumination allows for a short integration time for each pixel and the global electronic shutter allows

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for all of the pixels in the image sensor to be simultaneously sensitive. With a short exposure period for a brightly illuminated target, an image reader of the present invention is able to collect a sharp non-distorted image even when the target is moving relative to the image reader. In one embodiment, the exposure period is less than 3.7 milliseconds. In one embodiment in which the light sources are overdriven, light sources with different colors are employed. For example, in one such embodiment the image reader includes white and red LEDs, red and green LEDs, white, red, and green LEDs, or some other combination chosen in response to, for example, the color of the symbols most commonly imaged by the image reader. In this embodiment, the different colored LEDs are each alternatively pulsed at a level in accordance with the overall power budget. In another such embodiment, both colored LEDs are pulsed each time but each at a relatively lower power level so that the overall power budget is again maintained. In a further embodiment, red, green, and blue LED's can be interleaved to simulate white light.

Various embodiments of imaging module **1802** of image reader **100** are described with reference to FIG. **37**. LEDs **160** of imaging module **1802** may be divided into banks as indicated in the chart of FIG. **37**. Image reader **100** can be configured so that LEDs of each bank emits light in a certain emission wavelength band. In embodiment 8 depicted in the chart of FIG. **37**, image reader **100** is configured so that aiming LEDs **160***a*, **160***b* emit green light and all illumination LEDs **160***c* through **160***t* emit red light. Additional embodiments are described in the chart of FIG. **37**. Image reader **100** can be configured so that the light sources for the various banks may be energized simultaneously (e.g., bank 1, bank 2, bank 3, bank 4 simultaneously energized) or sequentially (e.g., bank 1, then bank 2, then bank 3, then bank 4) by the illumination timing control pulse **350**, **350'**, **350''**, **350'''**.

Referring again to FIGS. **9**, **10**A, **10**B, **10**C, and **10**D the process **300** also includes processing (step **316**) the photoconversion generated electric charge to produce image data. As discussed above, the processing can include, for example, amplifying the data generated from the incident radiation. The processing further includes storing the generated image data values in a shielded portion of each of the plurality of pixels. The process **300** additionally includes reading out and processing (step **320**) the stored image data values from the plurality of pixels. As discussed above, the processing can include amplifying the data generated from the incident radiation and converting the generated data into a digital signal. The processing (step **320**) can also include storing a set of digital signal values corresponding to incident light on the plurality of pixels of image sensor array module **182** as a frame of image data. Image reader **100** at step **320** may store into memory module **116** a frame of image data including a plurality of N-bit (grey scale) pixel values, each pixel value representing light incident at one of the plurality of pixels. In one embodiment, the reading out of the plurality of pixels is controlled by a read out timing control pulse **368** generated by the read out module **198** of the sensor array control module **186**. In one embodiment, the read out timing control pulse **368** includes a plurality of pulses transmitted to each of the plurality of pixels. In one embodiment, at least a portion of the illumination control timing pulse **350** occurs during the exposure control timing pulse **354**. In one such embodiment, the operation of the image collection module **104** including the sensor array control module **186** with the global electronic shutter control module **190** is coordinated with the operation of the illumination module **104** including the illumination control module **164** by the control module **112** to achieve the overlap in the illumination **350** and exposure **354** control timing signals.

In one embodiment as shown in FIG. **10**A, the exposure control timing pulse **354** begins after and finishes before the illumination control timing pulse **350**. The read out control timing pulse **368** begins at the conclusion of the illumination control timing pulse **350**. In another embodiment as shown in FIG. **10**B, the illumination control timing pulse **350'** begins after and finishes before the exposure control timing pulse **354'**. In this embodiment, the read out control timing pulse **368'** begins at the conclusion of the exposure control timing pulse **354'**. In further embodiments the exposure control timing pulse and the illumination control timing pulse overlap each other while occurring sequentially. In one such embodiment as shown in FIG. **10**C, this sequential operation can include the illumination control timing pulse **350''** starting, the exposure control timing pulse **354''** starting, the illumination control timing signal pulse **350''** ending, and then the exposure control timing pulse **354''** ending. In this embodiment, the read out control timing pulse **368''** begins at the conclusion of the exposure control timing pulse **354''**. In a further such embodiment as shown in FIG. **10**D, the sequential operation can include the exposure control timing pulse **354'''** starting, the illumination control timing pulse **350'''** starting, the exposure control timing pulse **354'''** ending, and then the illumination control timing signal pulse **350'''** ending. In this embodiment, the read out control timing pulse **368'''** begins at the conclusion of the illumination control timing signal pulse **350''''**. As discussed in connection with FIG. **10**E, each illumination control timing pulse **350**, **350'**, **350''**, **350'''** described herein may comprise a plurality of short duration individual pulses.

Referring again to imaging module **1802**, an image reader **100** having imaging module **1802** may have an operating mode in which aiming LEDs **160***a*, **160***b* are controlled to be off or de-energized during exposure control timing pulse **354**, **354'**, **354''**, or **354'''** so that light from LEDs **160***a*, **160***b* does not influence an image that is collected and transferred to decode module **150** or autodiscrimination module **152**. In another embodiment, aiming illumination LEDs **160***a*, **160***b*, in addition to illumination LEDs **160***c* through **160***t*, are controlled to be energized during exposure control timing pulse **354**, **354'**, **354''**, or **354'''**. Controlling aiming illumination LEDs **160***c* through **160***t* to be energized during exposure control timing pulse **354**, **354'**, **354''**, or **354'''** increases a signal strength of image data corresponding regions of substrate, s, onto which aiming pattern **1838** is projected.

With reference to process **300** (FIG. **9**), image reader **100** may be configured so that illumination control pulse **350**, **350'**, **350''**, or **350'''** at step **304** simultaneously energizes at least one of aiming LED **160***a* or **160***b* and at least one of illumination LEDs **160***c* through **160***t* so as to increase the intensity of illumination on substrate, s, and specifically the regions of substrate, s, onto which illumination pattern **1830** and aiming pattern **1838** are simultaneously projected. A decoding process carried out by decode module **150** or autodiscrimination module **152** where an image is collected pursuant to an exposure period wherein aiming LEDs **160***a*, **160***b* and illumination LEDs **160***c* through **160***t* are simultaneously energized may include a process wherein image data corresponding pattern **1838** (that is, image data corresponding to pixels of array onto which pattern **1838** is imaged) is selectively subjected to a decoding process such as a finder pattern locating process, a linear bar code symbol

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decode attempt or a quiet zone locating process. For example, with aiming pattern **1838** horizontally extending across a field of view, decode module **150** processing a collected full frame image may selectively analyze image data corresponding to center rows of image sensor **182** (i.e., image data corresponding to rows **2802** shown in FIG. **28***a*) for purposes of locating a finder pattern, decoding a linear bar code symbol, or locating a quiet zone where an image is collected pursuant to a frame exposure period wherein at least one aiming LED **160***a*, **160***b* and at least one illumination LED **160***c* through **160***t* are simultaneously energized. At step **320** of process **300** carried out with illumination control pulse **350**, **350'**, **350''**, or **350'''** simultaneously energizing at least one aiming illumination LED e.g., **160***a* and at least one illumination LED, e.g., **160***t*, image reader **100** may collect either a full frame or a "windowed frame" of image data as is described in greater detail in connection with FIGS. **28**A-**28**C. Image reader **100** may be configured so that where image reader **100** at step **320** collects a windowed frame of image data and at step **304** simultaneously illuminates at least one aiming illumination LED and at least one illumination LED, the windowed frame corresponds to the size and shape of illumination pattern **1838**. For example, where image reader **100** projects horizontal line aiming pattern **1838**, the windowed frame of image data readout at step **320** may be a windowed frame of image data corresponding to rows **2802** shown in FIG. **28**A onto which pattern **1838** is imaged which is then processed as described herein (e.g., by attempting to decode linear bar code symbol by locating a quiet zone or by locating a finder pattern). In embodiments of the invention wherein aiming illumination LEDs and illumination LEDs are simultaneously driven by illumination control pulse **350**, **350'**, **350''**, or **350'''**, the aiming LEDs **160***a*, **160***b* and illumination LEDs **160***c* through **160***t* may be overdriven throughout the duration of pulse **350**, **350'**, **350''**, or **350'''** as has been described herein.

In one embodiment the CMOS image array **182***a* can be implemented with a KAC-0331 640×480 VGA CMOS image sensor available from the Eastman Kodak Company. The KAC-0311 is more fully described in a technical description entitled, "KAC-0311 640×480 VGA CMOS IMAGE SENSOR Fully Integrated Timing, Analog Signal Processing & 10 bit ADC." Revision 1 dated Aug. 5, 2002 and available at http://www.kodak.com/global/plugins/acrobat/en/digital/ccd/products/cmos/KAC-0311LongSpec.pdf, hereby incorporated by reference in its entirety. The following is an edited summary of the operation of the KAC-0311 taken from the aforementioned "Full Specification." As summarized in this technical description, the KAC-0311 is a solid state active CMOS imager that integrates analog image acquisition, digitization, and digital signal processing on a single chip. The image sensor comprises a VGA format pixel array with 640×480 active elements. The image size is programmable by a user to define a window of interest. In particular, by programming the row and column start and stop operations, a user can define a window of interest down to a resolution of 1×1 pixel. In one embodiment of the KAC-0311 image sensor, the window can be used to enable a digital zoom operation of a viewport that can be panned. In another embodiment of the KAC-0311 image sensor, a constant field of view is maintained while subsampling is used to reduce the resolution the collected image.

The pixels of the KAC-0311 image sensor are on a 7.8 μm pitch. The pixel architecture is Kodak's pinned photodiode architecture. The KAC-0311 image sensor is available in a Monochrome version without microlenses, or with Bayer (CMY) patterned Color Filter Arrays without microlenses. In one embodiment of the KAC-0311 image sensor, integrated timing and programming controls are used to enable progressive scan modes in either video or still image capture operation. In a further embodiment of KAC-0311 image sensor, a user can program the frame rates while maintaining a constant master clock rate.

In the KAC-0311 image sensor, the analog video output of the pixel array is processed by an on-chip analog signal pipeline. In one embodiment of the KAC-0311 image sensor, correlated double sampling is used to eliminate pixel reset temporal and fixed pattern noise. In a further embodiment of the KAC-0311 image sensor, a frame rate clamp is used to enable contemporaneous optical black level calibration and offset correction. In yet another embodiment, the programmable analog gain of the KAC-0311 image sensor includes a global exposure gain to map the signal swing to the analog-to-digital converter input range. The programmable analog gain further includes white balance gain to perform color balance in the analog domain. In an additional embodiment, the analog signal processing chain of the KAC-0311 image sensor consists of column op-amp processing, column digital offset voltage adjustment, white balancing, programmable gain amplification, global programmable gain amplification, and global digital offset voltage adjustment. In one embodiment, the digitally programmable amplifiers are used to provide contemporaneous color gain correction for auto white balance as well as exposure gain adjustment. The offset calibration in various embodiments is done on a per column basis and globally. In addition, the per column offset correction can be applied by using stored values in the on-chip registers, and a ten-bit redundant signed digit analog-to-digital converter converts the analog data to a ten-bit digital word stream. In various embodiments of the KAC-0311 image sensor, the differential analog signal processing pipeline is used to improve noise immunity, the signal to noise ratio, and the system's dynamic range. In one embodiment, the serial interface of the KAC-0311 is an industry standard two line I^2C compatible serial interface. In another embodiment, power for the KAC-0311 image sensor is provided by a single 3.3V power supply. In various embodiments, the KAC-0311 image sensor has a single master clock and operates at speeds up to 20 MHz.

The operational and physical details of image sensors that can be used in the present invention and that are assigned to Eastman Kodak Company are also described in the U.S. Pat. No. 6,714,239 entitled "Active Pixel Sensor with Programmable Color Balance" and U.S. Pat. No. 6,552,323 entitled "Image Sensor with Shared Output Signal Line," each of which is hereby herein incorporated by reference in its entirety. The following provides a brief summary of material from U.S. Pat. No. 6,522,323. In particular U.S. Pat. No. 6,552,323 discloses an image sensor comprising a plurality of pixels arranged in a plurality of rows and columns. The image sensor is further disclosed to include a global electronic shutter. Pixels in the same row of the disclosed image sensor share a pixel output node and an output signal line. Further, the disclosure indicates that image signal separation within a row is achieved by having two separate row select signal lines per row, one for every other pixel within a row, and a 1:2 column output signal line de-multiplexing scheme for each pair of columns. A schematic diagram, here reproduced as FIG. **11**, shows two adjacent pixels **5**. Identifiers used in the schematic include the following: reset transistor with a reset gate (RG), transfer gate (TG), signal transistor (SIG), row select transistor with a row select gate (RSEL), photodetector (PD), and floating diffusion (FD). The opera-

tion of the global shutter is described at column 3 lines 25-45 of U.S. Pat. No. 6,552,323 with respect to the embodiment presented in FIG. **11** and timing diagrams, here reproduced as FIG. **12**. The disclosure indicates that readout commences by transfer of the integrated signal charge from the photodetectors **30***a*, **30***b* to the floating diffusions **10***a*, **10***b* in each pixel of the sensor simultaneously. Next, row select 1 (**15**) is turned on and the signal level of floating diffusion 1 (**10***a*) is sampled and held by the column circuit **20***a* by pulsing SS1. Row select 1 (**15**) is then turned off and row select 2 (**25**) is turned on and the signal level of floating diffusion 2 (**10***b*) is sampled and held by the column circuit **20***b* by pulsing SS2. The floating diffusions **10***a*, **10***b* in the row being read out are then reset by pulsing RG. Next row select 2 (**25**) is turned off and row select 1 (**15**) is turned on and the reset level of floating diffusion 1 (**10***a*) is sampled and held by the column circuit **20***a* by pulsing SR1. Row select 1 (**15**) is then turned off and row select 2 (**25**) turned on and the reset level of floating diffusion 2 (**10***b*) is sampled and held by pulsing SR2. The readout of the sampled and held signals of the column circuits **20***a*, **20***b* is then done prior to the same pixel readout scheme commencing in the next row of the image sensor.

In another embodiment, the CMOS image array **182***a* can be implemented with a KAC-9630 128(H)×98(V) CMOS image sensor. The KAC-9630 is more fully described in a technical specification entitled, "Device Performance Specification—Kodak KAC-9630 CMOS Image Sensor," September 2004, revision 1.1. This document is hereby herein incorporated by reference in its entirety. This document is available from Eastman Kodak (www.kodak.com), for example at http://www.kodak.com/global/plugins/acrobat/en/digital/ccd/products/cmos/KAC-9630LongSpec.pdf. This technical specification describes the KAC-9630 image sensor as a low power CMOS active pixel image sensor capable of capturing monochrome images at 580 frames per second. In addition the KAC-9630 image sensor is described as including an on-chip eight-bit analog-to-digital converter, fixed pattern noise elimination circuits and a video gain amplifier. The KAC-9630 is further described as having integrated programmable timing and control circuitry that allows for the adjustment of integration time and frame rate. The read out circuit in the KAC-9630 image sensor is described as capable of supporting a full frame read out on a single eight-bit digital data bus in less than 2 milliseconds. As indicated above, the KAC-9630 image sensor is described as including an integrated electronic shutter.

In another embodiment, the CMOS image array **182***a* can be implemented with a Micron image sensor such as the Wide VGA MT9V022 image sensor from Micron Technology, Inc., 8000 South Federal Way, Post Office Box 6, Boise, Id. 83707-0006. The MT9V022 image sensor is describe in more detail in the product MT9V099 product flyer available from Micron Technology (www.micron.com), for example at http://download.micron.com/pdf/flyers/mt9v022_(mi-0350)_flyer.pdf. This document is hereby herein incorporated by reference in its entirety.

In some embodiments, the image reader **100** is capable of operating in either a rolling shutter mode or a global electronic shutter mode. In one such embodiment, the rolling shutter mode is used as part of an automatic focusing operation and the global electronic shutter mode is used to collect image data once the proper focus has been determined. The process of determining the proper focus and collecting a subsequent image is described by the process **400** shown in FIG. **13**. Actuation module **124** may generate a trigger signal to initiate process **400** in response to e.g., a depressing of a trigger **216** by an operator or in response to an object being moved into a field of view of image reader **100**. In operation when a new image is collected by the image reader **100**, the image reader **100** illuminates (step **404**) a target containing an object, such as a bar code, and enters (step **408**) a rolling shutter operational mode in which a plurality of rows in the image reader's image sensor are sequentially exposed. As part of this operation, a frame exposure period can be defined as the time from the beginning of the exposure of the first row of the plurality of rows to the end of the exposure of the last row of the plurality of rows. In one embodiment, an imaging lens **212** of the image reader **100** is controlled to be in one of continuous motion or in stepwise continuous motion (step **414**) during at least a portion of the frame exposure period. As shown in the embodiment of FIG. **20**, image reader **100** may have a lens driver module **165** controlled by control module **112** or another module for moving imaging lens **212** to change a focus setting of image reader **100**. In one such embodiment, the optical system has a plurality of discrete settings. For each discrete setting, lens **212** forms a distinct image on the image sensor for objects located at a particular distance from the image reader **100**. In one embodiment, one extreme of the optical system's focusing range corresponds to focusing incident radiation from objects located at infinity. An object is considered to be at "infinity" if its incident light rays are essentially parallel. In one embodiment, another extreme of the optical system's focusing range is the near point of the optical system. The near point of the optical system is the closest distance an object can be brought with respect to the optical system where the optical system is still able to create a distinct image of the object. In another embodiment, the variation of in the focus of the optical system does not cover the entire range of the optical system. For example in one such embodiment, a focus setting of image reader **100** is varied between focus settings that are millimeters apart. In another embodiment, a focus setting of image reader **100** is varied between focus settings that are centimeters apart. Configuring reader **100** to include lens driver module **165** allows a scanner to operate over an extended depth of field.

With further reference to lens driver module **165**, various lens driving technologies and methods can be implemented. U.S. Pat. No. 4,350,418, incorporated by reference herein in its entirety, discloses a lens focus adjustment system including a distance adjusting ring, wherein position adjustment of a lens is achieved by rotation of the adjustment ring. U.S. Pat. No. 4,793,689, also incorporated herein by reference in its entirety, discloses a lens barrel having a hollow rotary ring rotatable about an optical axis that is disposed within a hollow of a hollow fixed cylinder with a bearing interposed there between, a moving cylinder moveable in response to rotation of the rotary ring, and a vibration wave motor disposed between the diametrical directions of the fixed cylinder and the rotary ring. U.S. Pat. No. 5,541,777, also incorporated herein by reference in its entirety, discloses an electromagnetic lens driver having a fixed member including an inside yoke and an outside yoke, an operationally disposed magnet, a moveable member for holding a body to be driven, a coil wound in an axial direction between the outside yoke and the inside yoke and position detector which detects the magnetic field of the operationally disposed magnet to generate a position indicating signal.

The process **400** also includes reading out (step **420**) image data from the plurality of exposed rows. This image data is analyzed (step **424**) by an automatic focusing algorithm, such as the contrast detection method or the phase detection method. Using the row focus image information,

the image reader **100** establishes (step **428**) a proper focus setting of lens **212** e.g., by determining a proper focus setting based on collected data and then moving the lens **212** to that setting or by assessing the present row image data to determine whether at the present focus setting, the image reader is acceptably focused. In various embodiments, the analysis of the image data can be performed by the image collection module **108**, the optics module, the control module **112**, or a dedicated auto-focusing module (e.g., an ASIC or FPGA dedicated for purposes of performing focus calculations). With the position of lens **212** properly established, the image reader **100** enters (step **432**) a global electronic shutter operational mode. It will be seen that in certain instances according to process **400**, image reader **100** may cease operation in a rolling shutter and commence operation in a global electronic shutter operational mode prior to reading out image data from each pixel of image sensor array module **182**. In the global electronic shutter operational mode, the image reader **100** collects (step **436**) a full frame of image data that is stored in memory module **116** and subsequently transferred to decode module **150** or autodiscriminating module **152** by control module **112**. According to this embodiment in which row image information is read out and analyzed during a time that the reader imaging lens **112** is controlled to be in motion, automatically focusing the image reader to image the target may be achieved within one frame of data. In various embodiments, the automatic focusing operations can be handled by a dedicated automatic focusing module or the focusing module can be incorporated into other modules such as the image collection module **108** and/or the control module **112**.

With further reference to the steps of process **400**, the step **424** of analyzing row image data to determine focus characteristics is further described with reference to the flow diagram of FIG. **21**, and the histogram plots of FIG. **22***a* and FIG. **22***b*. At step **2102** image reader **100** may construct a histogram plot of pixel values of the present row of image data read out at step **420**. FIG. **22**A is a histogram plot of pixel values of a row of data corresponding to a bi-tonal image (such as in a bar code symbol on a monochrome substrate) that is acceptably focused. Histogram plot **2108** represents a high contrast image and includes numerous pixel values at the high end of the grey scale, numerous pixel values at the low end of the grey scale, and few pixel values at the center grey scale range. FIG. **22**B is a histogram plot of pixel values of a row of data corresponding to a poorly focused bi-tonal image. The image data summarized by histogram **2110** is "flatter" lower contrast image data, meaning that it has fewer pixel values at extremes of the grey scale and a larger number of pixel values at a center of the grey scale. Accordingly, it can be seen that a focus level of an image can readily be determined utilizing image contrast information.

At step **2104** image reader **100** assesses the collected histogram data. At step **2104** image reader **100** may either determine an appropriate in-focus setting for lens **212** or else determine whether the histogram data extracted from the present row of image data indicates that the image reader is acceptably focused at the present lens setting or position. Where image reader **100** at step **2104** determines a proper setting for lens **212** based on the collected histogram data, the histogram data may be from the present row or based on a combination of present row data and preceding row data. In a further aspect, position or setting values of lens **212** are recorded so that the histogram information of each row of image data that is read out has associated lens position data indicating a position of lens **212** at the time at which the row information was collected. At step **2104**, a transfer function for determining an in-focus lens setting may utilize row contrast information as summarized in histogram plots, as well as lens position data indicating a position of lens **212** associated with each set of row data.

Referring to further steps of process **400**, image reader **100** at step **414** may control lens **212** to be in either continuous motion or in stepwise continuous motion. When controlled to be in continuous motion, lens **212** moves continuously throughout a time that sequentive rows of pixels of image sensor array module **182** are exposed and read out. When controlled to be in stepwise continuous motion, lens **212** repeatedly moves and stops throughout the time that rows of pixels of sensor module **182** are exposed and read out. In one embodiment of an image reader controlling lens **212** to be in stepwise continuous motion, image reader **100** continuously moves lens between two extreme points, a first, further field position and second, a nearer field position. In another embodiment of an image reader **100**, controlling lens **212** to be in stepwise continuous motion, image reader **100** continuously moves lens **212** between two extreme positions and intermittently stops lens **212** at one or more positions between the extreme positions. A lens **212** controlled to be in stepwise continuous motion can be considered to have motion periods, i.e., the times during which the lens moves, and stop periods, i.e., the times during which the lens is temporarily idle. In one embodiment of the invention, the motion of the lens **212** and a reading out of image data from rows of pixels are coordinated. For example, the lens movement and control of image sensor array module **182** can be coordinated such that an exposure period for one or more rows of image sensor array module **182** occurs during a stop period of lens **212** so that lens **212** is idle during an entire row exposure period. Further, while processing of image data corresponding to pixels exposed during motion phases of lens **212** is useful in certain embodiments, image reader **100** can be configured so that image data corresponding to pixels exposed during motion periods of lens **212** are discarded, e.g., during row analysis step **424**.

Specific embodiments of the process **400** generically described with reference to FIG. **13** are described with reference to the flow diagrams of FIGS. **23** and **24**. In the embodiment of FIG. **23**, image reader **100** at step **424** attempts to determine an in-focus lens setting based on collected row image data collected to that point. If at step **428***a*, image reader **100** determines that enough information has been collected to determine an in-focus position of lens **212**, image reader **100** determines an in-focus setting for lens **212** and proceeds to step **428***b* to move lens **212** to the determined in-focus position. If sufficient information has not been collected, image reader **100** returns to step **432** to collect additional row information. Image reader **100** may continue to read and process row image data while moving lens **212** at step **428***b*, e.g., for purposes of confirming that the determined in-focus position is correct. When lens **212** has been moved to the determined in-focus position, image reader **100** proceeds to step **432** to enter a global electronic shutter operational mode of operation. At the time that image reader **100** enters the global shutter operating mode (step **432**) image reader **100** may halt the motion of lens **212**. The image reader then proceeds to step **436** to collect a full frame of image data, and then to step **438** to transfer image data to one of the dataform decode module **150** or autodiscriminating module **152**.

In the embodiment of process **400** described with reference to FIG. **24**, image reader **100** establishes an in-focus

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setting of lens **212** by assessing at step **424** present row data (the most recent collected row data) to determine whether the present row data indicates that image reader **100** is presently in-focus. If image reader **100** at step **428***d* determines that image reader **100** is presently not in focus, image reader **100** returns to step **420** to collect additional row information. If at step **420** image reader **100** determines that the reader is presently in an in-focus position, image reader **100** proceeds to step **432** to enter a global electronic shutter mode of operation. At the time that image reader **100** enters the global shutter operating mode, (step **432**) image reader **100** may halt the motion of lens **212**. The image reader **100** then proceeds to step **436** to collect a full frame of image data, and then to step **438** to transfer image data to one of the dataform decode module **150** or autodiscriminating module **152**.

It will be understood with reference to process **400** or process **800** that image reader **100** in establishing an "in focus" position may designate a prospective or present position of lens **212** to be "in focus" on the basis of the prospective or present lens position rendering indicia in better focus that other available lens focus positions. Thus, where a lens focus position is not highly focused in a general sense, reader **100** may, nevertheless, designate the position as being "in focus" if it renders indicia more in focus than other available lens position. In one specific embodiment, lens **100** may be "toggled" between a limited number of discrete positions (e.g., two positions) when it is controlled to be in stepwise continuous motion. In such an embodiment, image reader **100** may designate one of the limited number of possible discrete positions to be the "in focus" positions if the lens position renders indicia more in focus than the remaining possible positions. Particularly in the configuration where lens **212** is "toggled" between a limited number of discrete positions, the focus determining steps may be omitted and the image data transferred directly to the decode module **150** or autodiscrimination module **152**. Particularly when there are a limited number of alternate focus positions, the in-focus position can readily be discriminated based on which position the results in a successful decode. Discriminating an in-focus position by way of decode attempts may reduce average decode time.

In a variation of the invention, image reader **100** at step **420** reads out a predetermined number of rows of image data and analyzes the predetermined number of rows at step **424**. The predetermined number of rows may be e.g., 2 rows, 3 rows, 10 rows or all of the rows (100+) rows of image sensor array **182**. Image reader **100** at step **424** may select the best focused (e.g., highest contrast) row out of the plurality of rows and determine that the recorded focus setting associated with the best focused row is the "in-focus" setting of image reader **100**. Alternatively, image reader **100** may calculate-in-focus setting data utilizing data image collected over several rows. When a focus setting has been determined, in any one of the above variations, image reader **100** may first enter global electronic shutter operational mode at step **432**, and then move lens **212** into the determined focus position setting or else image reader **100** may alternatively move lens **212** to the determined lens setting prior to entering the global electronic shutter operational mode at step **432** or these two operations may occur at the same time.

In another embodiment of the automatic focusing operation, as described later in connection with FIGS. **25-30**B, the global electronic shutter operational mode may be used during both the focusing period and the data collection period. According to process **800** as described herein, during the autofocusing period a limited, "windowed" frame of image data may be collected for each variation in the focus setting or position. For example, only the central region, or a central group of scan lines—such as the middle ten scan lines, of the image sensor is read out and analyzed by the focus determination algorithm. According to this embodiment, the limited frame of data provides adequate information for the focus determination algorithm while significantly decreasing the time required to collect the series of frames required to focus the image reader.

In alternative embodiments, the specific order of the steps in the process **400** or process **800** can be altered without departing from the inventive concepts contained therein. In various other embodiments, the circuitry implementing the rolling shutter operation and the circuitry implementing the global electronic shutter operation can be implemented on the same CMOS chip or one or both of the circuitry components can be implemented on separate dedicated chips. In an additional embodiment, the rolling shutter functionality and the global electronic shutter operation can be combined in a single module that includes hardware, software, and/or firmware.

In another embodiment of the image reader **100** that operates in either a rolling shutter or a global electronic shutter mode, the image reader **100** is able to dynamically shift between the global electronic shutter operational mode and the rolling shutter operational mode. In one such embodiment, the image reader **100** shifts from the default global electronic shutter operational mode to the rolling shutter operational mode when the integration time is shorter than a given threshold. Many commercially available imagers are implemented with light shields that allow some amount of light leakage into the storage element or with electronic switches that do not completely isolate the storage element from the photosensitive element. As a result of this, the contents of the storage element can be adversely influenced by the ambient illumination incident upon the imager after the charge has been transferred to the storage element. The following provides a numeric example of such operation.

In general, the shutter efficiency of a CMOS image sensor with global electronic shutter capabilities specifies the extent to which the storage area on the image sensor is able to shield stored image data. For example, if a shutter has an efficiency of 99.9%, then it takes an integration time (also known as exposure time) that is 1,000 times longer to generate the same amount of charge in the shielded portion as in the unshielded portion of the image sensor. Therefore, in an image capture cycle, the following equation provides an indication of the light irradiance on the imager from the ambient light that can be tolerated during the time period after the image is shifted into the storage region relative to the light irradiance on the imager from the object illuminated with the ambient illumination and the light sources **160** during the time period before the image is shifted into the storage region while not exceeding a desired degradation percentage. The equation can also address the case where the light incident upon the imager is the same during the entire imaging cycle. In both instances, one needs to know the minimum integration that can be used without the introduction of a maximum degradation.

$$(\text{Amb. Irrad})*T\text{frame}*(100\%-\%\text{ eff})=(\text{Amb. Irrad}+\text{Light Source Irrad})*T\text{exposure}*(\%\text{ deg})$$

In many instances the light on the imager is unchanged during the exposure period and during the remainder of the frame. In this situation the light irradiance on the imager is constant, and it is possible to solve for the minimum

integration time that can be used without the light leakage excessively perturbing the desired image. Solving the equation in this case, allows the calculation of the minimum integration period for a specific degradation. The following constant irradiance numeric example is for a shutter efficiency of 99.9%, a frame rate of 20 ms, and a maximum tolerated degradation of 5%.

$$20\text{ ms}*(100\%-99.9\%)=(T\text{exposure}*5\%)$$

or solving for the minimum exposure time that can be used without incurring a degration of more than 5%:

$$T\text{exposure}=0.4\text{ ms.}$$

Thus if the integration time during image capture is shorter than 0.4 ms, then the degradation leakage (both optical or electrical) will cause an error to be introduced of 5% or greater.

In one embodiment that addresses image degradation introduced by excessive ambient light, the image reader **100** shifts to rolling shutter operation when the integration time becomes shorter than a level determined with respect to the frame rate, maximum allowable degradation and shutter efficiency of the image reader. A process **600** for shifting operational modes in response to short integration times is shown in FIG. **14**. Actuation module **124** may generate a trigger signal to initiate process **600** in response to e.g., a depressing of a trigger **216** by operator or in response to an object being provided into a field of view of image reader **100**. The process **600** includes storing (step **604**) a calculated minimum integration time. In one embodiment, this threshold is determined in accordance with the equations presented above. Some of the inputs to these equations, such as the shutter efficiency, maximum acceptable image degradation leakage, and frame rate, can be configured in the image reader **100** as part of its initial setup or at a later time. The process **600** also includes collecting (step **608**) image data. As part of the collection of image data, an exposure time for the current environmental conditions is established (step **612**) by the sensor array control module **186**. In various embodiments, this exposure time is established by the global electronic shutter control module **190**, the optics module **178**, or another appropriate module in the image reader **100**. To determine whether the operational mode of the image reader **100** should shift from global shutter to rolling shutter, the established exposure time is compared (step **616**) with the minimum integration time threshold. If the established integration time is shorter than the calculated minimum integration time threshold, then the operational mode of the image reader **100** is shifted (step **620**) from global electronic shutter to rolling shutter. If the established integration time is greater than or equal to the calculated minimum integration time threshold, then the global electronic shutter operational mode (step **628**) is maintained.

Further embodiments of the invention are described with reference to FIG. **15**A, and the flow diagrams of FIGS. **31** and **32**. As shown in FIG. **15**A, image reader **100** can be configured to have user selectable configuration settings. For example, as shown in FIG. **15**A, image reader **100** may present on display **504** a graphical user interface (GUI) menu option display screen **3170** which presents to an operator the user selectable configuration options of a rolling shutter operational mode and a global shutter operational mode. GUI display screens may be configured with tool kits associated with certain available operating systems such as WINDOWS CE, which may be installed on image reader **100**. When reader **100** is configured to include a browser or is otherwise configured with suitable parsers and interpreters, GUI **3170** can be created using various open standard languages (e.g., HTML/JAVA, XML/JAVA). In the embodiment of FIG. **15**A, GUI icon **3152** is a rolling shutter selection button and GUI icon **3154** is a global electronic shutter menu option. When icon **3152** is selected, image reader **100** is configured so that when image reader **100** receives a next trigger signal as described herein to initiate a decode attempt, image reader **100** collects image data utilizing a rolling shutter operating mode without utilizing the global electronic operational mode. When icon **3154** is selected, image reader **100** is configured so that when image reader **100** receives a next trigger signal to initiate a decode attempt, image reader **100** collects image data utilizing the global electronic shutter operational mode without utilizing the rolling shutter operational mode. GUI **3170** can be created to permit additional user selectable configuration options. In the embodiment of FIG. **15**A, selection of button **3156** (which may be in text or icon form) configures image reader **100** so that process **300** is executed the next time a trigger signal is received. Selection of button **3158** configures image reader **100** so that process **400** is executed a next time a trigger signal is received. Selection of button **3160** configures image reader **100** so that process **600** is executed a next time a trigger signal is received. Selection of button **3162** configures image reader **100** so that process **800** is executed a next time a trigger signal is received. Selection of button **3164** configures image reader **100** so that image reader **100** is in "image capture" mode of operation such that a next time a trigger signal is received, image reader collects image data such as a 2D full frame of image data and outputs an image (e.g., to display **504** or a spaced apart device) without transferring the collected image data to module **150** or module **152**. In shipping applications, it may be beneficial to capture images in an "image capture" mode corresponding to moving objects (e.g., a moving delivery vehicle, a package on an assembly line). Accordingly, it will be seen that execution of an image capture mode utilizing a global shutter operational mode of operation yields significant advantages, in that image distortion is reduced using a global shutter operational mode. The selection between a rolling shutter configuration and a global electronic shutter configuration or the configurations associated with buttons **3156**, **3158**, **3160**, **3162**, and **3164** can also be made with use of commands of a software development kit (SDK). A system can be created so that SDK-created commands (e.g., a "ROLLING SHUTTER" and a "GLOBAL SHUTTER" command) causing image reader **100** to be in one of a rolling shutter configuration and a global electronic shutter configuration can be selected at a host terminal spaced apart from image reader **100** and transmitted to image reader **100** to reconfigure reader **100**.

Referring to the flow diagram of FIG. **31**, an operator selects between a rolling shutter configuration and a global electronic shutter configuration at step **3102**. If an operator selects the rolling shutter configuration, image reader **100** proceeds to step **3104**. At step **3104** image reader **100** is driven from an idle state to an active reading state by the generation of a trigger signal (e.g., by manual actuation of trigger **216** or another method) and then automatically executes steps **3106** and **3108**. At step **3106** image reader **100** collects image data utilizing a rolling shutter operational mode and at step **3108** the image data collected at step **3106** is transferred to dataform decode module **150** or autodiscrimination module **152** to decode or otherwise process the image data. If at step **3102** a global electronic shutter mode is selected, image reader **100** proceeds to step **3118**. At step **3118** image reader **100** is driven from an idle state to an

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active reading state by the generation of a trigger signal (e.g., by manual actuation of trigger **216** or another method) and then automatically executes steps **3118** and **3120**. At step **3118** image reader **100** collects image data utilizing a global electronic shutter operational mode and at step **3122** the image data collected at step **3118** is transferred to dataform decode module **150** or autodiscrimination module **152** to decode or otherwise process the image data.

Another embodiment of the invention is described with reference to the flow diagram of FIG. **32**. In the embodiment described with reference to the flow diagram of FIG. **32**, image reader **100** is configured to collect image data and attempt to decode image data utilizing a rolling shutter operational mode and a global shutter operational mode. At step **3202** a trigger signal is generated as described herein (e.g., by manual actuation of trigger **216** or another method) to drive image reader **100** from an idle state to an active reading state and all of steps **3204**, **3206** may be automatically executed thereafter. At step **3204** image reader **100** enters a rolling shutter operational mode. At step **3206** image reader **100** collects image data such as a full frame of image data or a windowed frame of image data utilizing the rolling shutter operational mode. At step **3208** image reader **100** transfers the image data collected at step **3206** to dataform decode module **150** and/or autodiscrimination module **152**. Dataform decode module **150** or autodiscrimination module **152** may decode or otherwise process the image data collected and output a result (e.g., output a decoded bar code message to display **504** and or a spaced apart device). At step **3118** image reader **100** enters a global electronic shutter operational mode. At step **3212** image reader **100** collects image data utilizing the global electronic shutter operational mode. The image data collected at step **3212** may be full frame or a windowed frame image data. At step **3214** image reader **100** transfers the image data collected at step **3212** to dataform decode module **150** or autodiscrimination module **152**. Dataform decode module **150** or autodiscrimination module **152** may decode or otherwise process the image data collected and output a result (e.g., output a decoded bar code message to display **540** and/or a spaced apart device). As indicated by control loop arrow **3216**, image reader **100** may automatically repeat steps **3204**, **3206**, **3208**, **3210**, **3212**, and **3214** until a stop condition is satisfied. A stop condition may be e.g., the generation of a trigger stop signal (as may be generated by the release of trigger **216**) or the successful decoding a predetermined number of bar code symbols.

Another process according to the invention is described with reference to the flow diagram of FIG. **25**. Process **800** is similar to process **400** in that it involves the processing of a limited amount of image data collected during a time that lens **212** is controlled to be in motion. With process **400** and with process **800** an in-focus position of lens **212** is quickly established. Whereas process **400** involves utilization of an image sensor array module **182** operated, at different times during the course of the process, in a first rolling shutter operational mode and a second, subsequently executed global electronic operational mode, process **800** may be implemented with use of one of the selectively addressable image sensor array modules described herein operated throughout the process in either one of a rolling shutter mode of operation or in a global electronic mode of operation.

With further reference to process **800**, actuation module **124** at step **802** initiates process **800** by generating a trigger signal, e.g., in response to a depression of a trigger **216**, a sensing of an object in a field of view of image reader or receipt of a command from a spaced apart device. At step **814** image reader **100** sets lens **212** into motion. At step **814** image reader **100** may control lens **212** to be in one of continuous motion or stepwise continuous motion.

At step **820** image reader **100** reads out a "windowed frame" of image data from image sensor array module **182**. CMOS image sensors can be operated in a windowed frame operating mode. In a windowed frame operating mode, image data corresponding to only a selectively addressed subset of all pixels of an image sensor array is read out. Examples of image reader **100** operating in windowed frame operating modes are described with reference to FIGS. **28**A, **28**B and **28**C, wherein image sensor arrays are represented with each square of the grid representing a 10×10 block of pixels, and wherein shaded regions **2802**, **2804**, and **2806** represent pixels that are selectively addressed and selectively subjected to readout. In the embodiment of FIG. **28**A, a windowed frame operating mode is illustrated wherein windowed image data is read out of image sensor array **182** by selectively addressing and reading out only centerline pattern of pixels consisting of a set of rows of pixels at a center of image sensor array module **182**. Alternatively, in a windowed frame operating mode image reader **100** may selectively address and selectively read out image data from a single row of pixels of image sensor array module **182**. Further, in a windowed frame operating mode, image reader **100** may selectively address, and selectively read out image data from rows **2802***a* and **2802***b*. In the embodiment of FIG. **28**B, a windowed frame operating mode is illustrated wherein windowed image data is read out of image sensor array module **182** by selectively addressing and reading out only a collection of positionally contiguous pixels (i.e., a collection of pixels that are adjacent to one another) at a center of image sensor array module **182**. In the embodiment of FIG. **28**C, a windowed frame operating mode is illustrated wherein windowed image data is read out of image sensor array module **182** by selectively reading out spaced apart clusters of 10×10 blocks of positionally contiguous pixels. In all of the windowed frame operating modes described with reference to FIGS. **28**A, **28**B and **28**C, image data corresponding to less than half of the pixels of the image sensor is selectively addressed and read out. When operating in a windowed frame operating mode image reader **100** may collect image data corresponding to light incident on pixels in one or more of the patterns illustrated in FIG. **28**A, **28**B or **28**C or another pattern. Such collections of image data may include a collection of gray scale values and may be termed windowed frames of image data.

A windowed frame operating mode described herein is contrasted with an alternative operating mode in which a full frame of image data is stored into memory module **116**, and then a portion of that full frame of image data is designated as a region of interest (i.e., a "sample" region) which is subject to further processing. In a windowed frame operating mode a frame of image data may collected in a fraction of the time required to collect a full frame of image data.

With further reference to process **800** image reader **100** at step **824** analyzes a windowed frame of image data to determine focus characteristics of image reader **100**. The step of analyzing windowed frame image data to determine focus characteristics is further described with reference to the flow diagram of FIG. **29**, and the histogram plots of FIG. **30**A and FIG. **30**B. At step **4102** image reader **100** may construct a histogram plot of pixel values of the present windowed frame of image data read out at step **820**. FIG. **30**A is a histogram plot of pixel values of a row of data corresponding to a bi-tonal image (such as in a bar code symbol on a monochrome substrate) that is acceptably focused. Histogram plot **4108** represents a high contrast

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image and includes numerous pixel values at the high end of the grey scale, numerous pixel values at the low end of the grey scale, and few pixel values at the center grey scale range. FIG. **30**B is a histogram plot of pixel values of a windowed frame of image data corresponding to a poorly focused bi-tonal image. The image data summarized by histogram **4110** is "flatter," lower contrast image meaning that it has fewer pixel values at extremes of the grey scale and a larger number of pixel values at a center of the grey scale. Accordingly, it can be seen that a focus level of an image can readily be determined utilizing image contrast information.

At step **4104**, image reader **100** assesses the collected histogram data. At block **4104** image reader **100** may either determine an appropriate in-focus setting for lens **212** or else determine whether the histogram data extracted from the present row of image data indicates that the image reader **100** is acceptably focused at the present lens position. Where image reader **100** at step **4104** determines a proper setting for lens **212** based on the collected histogram data, the histogram data may be from the present windowed frame of image data or based on a combination of present windowed frame of image data and preceding data of previously collected one or more frames of windowed image data. In a further aspect, position or setting values of lens **212** are recorded so that the histogram information of each row of image data that is read out and analyzed has associated lens position data indicating a position of lens **212** at the time at which the windowed frame of image data information was collected. At step **4104** a transfer function for determining an in-focus lens setting may utilize windowed frame contrast information as summarized in histogram plots, as well as lens position data indicating a position of lens **212** associated with each collected windowed frame of image data.

Referring to further steps of process **800**, image reader **100** at step **814** may control lens **212** to be in either continuous motion or in stepwise continuous motion. When controlled to be in continuous motion, lens **212** moves continuously throughout a time that pixels corresponding to a windowed frame of image data are exposed and read out. When controlled to be in stepwise continuous motion, lens **212** repeatedly moves and stops throughout the time that pixels corresponding to a windowed frame of image data are exposed and read out. In one embodiment of an image reader **100** controlling lens **212** to be in stepwise continuous motion, image reader **100** continuously moves lens between two extreme points, a first further-field position and second, a nearer-field position. In another embodiment of an image reader **100** controlling lens **212** to be in stepwise continuous motion, image reader **100** continuously moves lens **212** between two extreme positions and intermittently stops lens **212** at one or more positions between the extreme positions. A lens **212** controlled to be stepwise continuous motion can be considered to have motion periods, i.e., the times during which the lens moves, and stop periods corresponding the time the lens is temporarily idle. In one embodiment of the invention, the motion of the lens **212** and a reading out of image data from rows of pixels are coordinated. For example, the stepwise movement of lens **212** and control of image sensor array module **182** can be coordinated such that a stop period of a lens in stepwise continuous motion occurs during an exposure period for exposing pixels corresponding to a windowed frame of image data and motion periods occur before and after such an exposure period. Further, while processing of image data corresponding to pixels exposed during motion periods of lens **212** is useful in certain embodiments, image reader **100** can be configured so that image data corresponding to pixels exposed during motion periods of lens **212** are discarded, e.g., during analysis step **824**.

Specific embodiments of the process **800** generically described with reference to FIG. **25** are described with reference to the flow diagrams of FIGS. **26** and **27**. In the embodiment of FIG. **26**, image reader **100** at step **824** attempts to determine an in-focus setting based on collected windowed frame image data collected to that point. If at block **828***a* image reader **100** determines that enough information has been collected to determine an in-focus position of image reader **100**, image reader **100** proceeds to step **828***b* to move the lens to the determined in-focus position. If sufficient information has not been collected, image reader returns to step **820** to collect additional windowed frame information. Image reader **100** may continue to read and process windowed frame image data while moving lens **212** at step **828***b*, e.g., for purposes of confirming that the determined in-focus position is correct. When lens **212** has been moved to the determined in-focus position image reader **100** proceeds to step **836** to collect a full frame of image data (e.g., in accordance with process **300**), and then proceeds to step **838** to transfer the collected image data to one of dataform decode module **150** or autodiscriminating module **152**.

In the embodiment of process **800** described with reference to FIG. **27**, image reader **100** establishes an in-focus setting of lens **212** by assessing at step **824** present windowed frame image data (the most recent collected windowed frame data) to determine whether the present windowed frame image data indicates that image reader **100** is presently in-focus. If image reader **100** at step **828***c* determines that image reader **100** is presently not in focus, image reader **100** returns to step **820** to collect additional windowed frame information. If at step **828** image reader **100** determines that the reader is presently in an in-focus position, image reader **100** proceeds to step **836** to collect a full frame of image data, (e.g., in accordance with process **300**), and then proceeds to step **838** to transfer the collected image data to one of dataform decode module **150** or autodiscriminating module **152**.

In a variation of the invention, image reader **100** at step **820** may read out a predetermined number of windowed frames of image data, and at step **824** may analyze a predetermined number of windowed frames of image data. The windowed frames of image data may have the same pattern (e.g., always the pattern of FIG. **28**A) or may have alternating patterns (e.g., first the pattern of FIG. **28**A, next the pattern of FIG. **28**B, and next the pattern of FIG. **28**C). In another variation, image reader **100** may transfer each collected windowed frame of image data, subsequent to collection, to dataform decode module **150** and/or autodiscrimination module **152**. At step **824**, image reader **100** analyzes the predetermined number of frames of image data in order to determine an in-focus setting of image reader **100**. In determining an in-focus setting, image reader **100** may select the in-focus setting associated with the best focused (highest contrast) windowed frame of image data out of the plurality of windowed frames of image data or else image reader **100** may calculate a focus setting utilizing image data from the plurality of windowed frames collected. In any of the variations of process **800**, image reader **100** may collect a full frame of image data at step **836** after determining an in-focus setting of image reader **100** before or after moving lens **212** to the determined setting position to establish an in-focus setting.

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It will be understood with reference to process **400** and process **800** that image reader **828** in establishing an "in focus" position may designate a prospective or present position of lens **212** to be "in focus" on the basis of the prospective or present lens position rendering target indicia in better focus than other available lens focus positions. Thus, where a lens focus position is not highly focused in a general sense reader **100** may, nevertheless, designate the position as being "in focus" if it renders target indicia more in focus than other available lens position. In one specific embodiment, lens **212** may be "toggled" between a limited number of discrete positions (e.g., two positions) when it is controlled to be in stepwise continuous motion. In such an embodiment, image reader **100** may designate one of the limited number of possible discrete positions to be the "in-focus" position if the lens position renders target indicia more in focus than the remaining possible positions. Particularly in the configuration where lens **212** is "toggled" between a limited number of discrete positions, the focus determining steps may be omitted and the image data transferred directly to the decode module **150** or autodiscrimination module **152**. Particularly when there are a limited number of alternate focus positions, the in-focus position can readily be discriminated based on which position the results in a successful decode. Discriminating an in-focus position by way of decode attempts may reduce average decode time.

It is recognized that some available image sensor arrays have configurations or operation modes in which a limited number of edge columns/and or rows are not read out because of packaging concerns (e.g., edge pixels are covered by packaging material of the chip) or because of a configuration to a particular aspect ratio. Where image data from an image sensor is read out from all of the pixels of the image sensor or substantially all the pixels excluding a limited number of row and/or column edge pixels, such image data collecting is regarded herein as a collecting of a full frame of image data.

With reference to process **400** and process **800**, it has been described that lens **212** can be controlled to be in one of continuous motion or stepwise continuous motion. It will be seen that when lens **212** is controlled to be in continuous motion, a focus setting of image reader **100** is controlled to vary over time. When lens **212** is controlled to be in stepwise continuous motion, a focus setting of lens **212** and, therefore, of image reader **100** is controlled to vary stepwise over time. Further, when lens **212** in accordance with process **400** or process **800** is in a motion period while being controlled to be in stepwise continuous motion, a focus setting of lens **212** is in a varying state. During a stop period of lens **212** while lens **212** is being controlled to be in stepwise continuous motion, a focus setting of image reader **100** is in a temporarily idle state.

Referring again to FIG. **1**A, the following description provides additional details on modules in the image reader **100** presented above. In various embodiments, the control module **112** can include a central processing unit including on-chip fast accessible memory, application specific integrated circuits (ASICs) for performing specialized operations, as well as software, firmware and digitally encoded logic. The memory module **116** can comprise any one or more of read-only (ROM), random access (RAM) and non-volatile programmable memory for data storage. The ROM-based memory can be used to accommodate security data and image reader operating system instructions and code for other modules. The RAM-based memory can be used to facilitate temporary data storage during image reader operation. Non-volatile programmable memory may take various forms, erasable programmable ROM (EPROM) and electrically erasable programmable ROM (EEPROM) being typical. In some embodiments, non-volatile memory is used to ensure that the data is retained when the image reader **100** is in its quiescent or power-saving "sleep" state.

The I/O module **120** is used to establish potentially bi-directional communications between the image reader **100** and other electronic devices. Examples of elements that can comprise a portion of the I/O module **120** include a wireless or wired Ethernet interface, a dial-up or cable modem interface, a USB interface, a PCMCIA interface, a RS232 interface, an IBM Tailgate Interface RS485 interface, a PS/2 keyboard/mouse port, a specialized audio and/or video interface, a CompactFlash interface, a PC Card Standard interface, a Secure Digital standard for memory, a Secure Digital Input Output for input/output devices and/or any other standard or proprietary device interface. A CompactFlash interface is an interface designed in accordance with the CompactFlash standard as described in the CompactFlash Specification version 2.0 maintained at the website http://www.compactflash.org. The CompactFlash Specification version 2.0 document is herein incorporated by reference in its entirety. A PC Card Standard interface is an interface designed in accordance with the PC Card Standard as described by, for example, the PC Card Standard 8.0 Release—April 2001 maintained by the Personal Computer Memory Card International Association (PCMCIA) and available through the website at http://www.pcmcia.org. The PC Card Standard 8.0 Release—April 2001 Specification version 2.0 document is hereby herein incorporated by reference in its entirety.

The actuation module **124** is used to initiate the operation of various aspects of the image reader **100** such as data collection and processing in accordance with process **300**, process **400**, process **600** or process **800** as described herein. All of the steps of process **300**, process **400**, process **600** and process **800** may be automatically executed in response to an initiation of the respective process by actuation module **124**. Image reader **100** may be configured so that the steps of process **300**, process **400**, process **600**, and process **800** continue automatically when initiated until a stop condition is satisfied. A stop condition may be e.g., the generation of a trigger stop signal (as may be generated by the release of trigger **216**) or the successful decoding a predetermined number of bar code symbols. In the hand held image reader **100***a* discussed above, the actuation module comprises the trigger **216** which, when depressed, generates a trigger signal received by control module **112** which, in turn, sends control signals to appropriate other modules of image reader **100**. In one embodiment of a fixed mounted embodiment of the image reader **100**, the actuation module **124** comprises an object sensing module that generates a trigger signal to initiate the operation of the image reader **100** when the presence of an object to be imaged is detected. When a trigger signal is generated, image reader **100** is driven from an idle state to an active reading state. Actuation module **124** may also generate a trigger signal in response to receipt of a command from a local or remote spaced apart device.

The user feedback module **128** is used to provide sensory feedback to an operator. In various embodiments, the feedback can include an auditory signal such as a beep alert, a visual display such as an LED flashing indicator, a mechanical sensation such as vibration in the image reader **100**, or any other sensory feedback capable of indicating to an operator the status of operation of the image reader **100** such as a successful image capture.

The display module **132** is used to provide visual information to an operator such as the operational status of the image reader **100** including, for example, a remaining battery and/or memory capacity, a mode of operation, and/or other operational or functional details. In various embodiments, the display module **132** can be provided by a LCD flat panel display with an optional touch-pad screen overlay for receiving operator tactile input coordinated with the display.

The user interface module **134** is used to provide an interface mechanism for communication between an operator and the image reader **100**. In various embodiments, the user interface module **134** comprises a keypad, function specific or programmable buttons, a joystick or toggle switch and the like. If the display module **132** includes a touch-pad screen overlay as mentioned above, the display module can incorporate some of the input functionality alternatively provided by elements in the user interface module **134**.

In some embodiments, the RFID module **136** is an ISO/IEC 14443 compliant RFID interrogator and reader that can interrogate a RFID contactless device and that can recover the response that a RFID tag emits. The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) are bodies that define the specialized system for worldwide standardization. In other embodiments, the RFID module **136** operates in accordance with ISO/IEC 10536 or ISO/IEC 15963. Contactless Card Standards promulgated by ISO/IEC cover a variety of types as embodied in ISO/IEC 10536 (Close coupled cards), ISO/IEC 14443 (Proximity cards), and ISO/IEC 15693 (Vicinity cards). These are intended for operation when very near, nearby and at a longer distance from associated coupling devices, respectively. In some embodiments, the RFID module **136** is configured to read tags that comprise information recorded in accordance with the Electronic Product Code (EPC), a code format proposed by the Auto-ID Center at MIT. In some embodiments, the RFID module **136** operates according to a proprietary protocol. In some embodiments, the RFID module **136** communicates at least a portion of the information received from an interrogated RFID tag to a computer processor that uses the information to access or retrieve data stored on a server accessible via the Internet. In some embodiments, the information is a serial number of the RFID tag or of the object associated with the RFID tag.

In some embodiments, the smart card module **140** is an ISO/IEC 7816 compliant smart card reader with electrical contact for establishing communication with a suitably designed contact chip based smart card. The smart card module **140** is able to read and in some cases write data to attached smart cards.

In some embodiments, the magnetic stripe card module **144** is a magnetic stripe reader capable of reading objects such as cards carrying information encoded in magnetic format on one or more tracks, for example, the tracks used on credit cards. In other embodiments, the magnetic stripe card module **144** is a magnetic character reading device, for reading characters printed using magnetic ink, such as is found on bank checks to indicate an American Bankers Association routing number, an account number, a check sequence number, and a draft amount. In some embodiments, both types of magnetic reading devices are provided.

In some embodiments of the image reader **100**, the functionality of the RFID module **136**, the smart card module **140**, and the magnetic stripe card module **144** are combined in a single tribrid reader module such as the Panasonic's Integrated Smart Card Reader model number ZU-9A36CF4 available from the Matsushita Electrical Industrial Company, Ltd. The ZU-9A36CF4 is described in more detail in the Panasonic Specification number MIS-DG60C194 entitled, "Manual Insertion Type Integrated Smart Reader" dated March 2004 (revision 1.00). This document is hereby herein incorporated by reference in its entirety.

The decoder module **150** is used to decode target data such as one and two-dimensional bar codes such as UPC/EAN, Code 11, Code 39, Code 128, Codabar, Interleaved 2 of 5, MSI, PDF417, MicroPDF417, Code 16K, Code 49, MaxiCode, Aztec, Aztec Mesa, Data Matrix, Qcode, QR Code, UCC Composite, Snowflake, Vericode, Dataglyphs, RSS, BC 412, Code 93, Codablock, Postnet (US), BPO4 State, Canadian 4 State, Japanese Post, KIX (Dutch Post), Planet Code, OCR A, OCR B, and the like. In some embodiments, the decoder module also includes autodiscrimination functionality that allows it to automatically discriminate between a plurality of bar code such as those listed above. Certain functionality of the decoder **150**, such as the measurement of characteristics of decodable indicia, is described in the related U.S. application Ser. No. 10/982,393, filed Nov. 5, 2004, entitled "Device and System for Verifying Quality of Bar Codes." This application is hereby herein incorporated by reference in its entirety.

Another example of an image reader **100** constructed in accordance with the principles of the invention is the portable data terminal **100*b*** shown in different perspective drawings in FIGS. **15**A, **15**B, and **15**C. FIG. **15**A shows a top perspective, FIG. **15**B shows a front perspective view, and FIG. **15**C shows a back perspective view. As shown, the portable data terminal **100*b*** in one embodiment includes interface elements including a display **504**, a keyboard **508**, interface buttons **512** for example for positioning a cursor, a trigger **216**, and a stylus **520** with a stylus holder **524** (not shown). The portable data terminal **100*b*** further includes a lens **212*b*** and light sources **160*b***. In additional embodiments, the portable data terminal can have its functionality enhanced with the addition of multiple detachable computer peripherals. In various embodiments, the computer peripherals can include one or more of a magnetic stripe reader, a biometric reader such as a finger print scanner, a printer such as a receipt printer, a RFID tag or RF payment reader, a smart card reader, and the like. In various embodiments, the portable data terminal **100*b*** can be a Dolphin 7200, 7300, 7400, 7900, or 9500 Series Mobile Computer available from Hand Held Products, Inc., of 700 Visions Drive, P.O. Box 208, Skaneateles Falls, N.Y. and constructed in accordance with the invention. Various details of a hand held computer device, in particular the device's housing, are described in more detail in the related U.S. application Ser. No. 10/938,416, filed Sep. 10, 2004, entitled "Hand Held Computer Device." This application is hereby herein incorporated by reference in its entirety.

The portable data terminal **100*b*** further includes an electro-mechanical interface **532** such as a dial-up or cable modem interface, a USB interface, a PCMCIA interface, an Ethernet interface, a RS232 interface, an IBM Tailgate Interface RS485 interface, a CompactFlash interface, a PC Card Standard interface, a Secure Digital standard for memory interface, a Secure Digital Input Output for input/output devices interface and/or any other appropriate standard or proprietary device interface. In various embodiments, the electro-mechanical interface **532** can be used as part of attaching computer peripherals.

An electrical block diagram of one embodiment of the portable data terminal **100***b* is shown in FIG. **16**. In the embodiment of FIG. **16**, an image collection module **108***b* includes an image engine including two-dimensional image sensor **536** provided on image sensor chip **546** and associated imaging optics **544**. The associated imaging optics **544** includes the lens **212***b* (not shown). Image sensor chip **546** may be provided in an IT4000 or IT4200 image engine of the type available from Hand Held Products, Inc. of Skaneateles Falls, N.Y. constructed in accordance with the invention and may be a suitable commercially available chip such as the Kodak KAC-0311 or the Micron MT9V022 image sensor array described above. The portable data terminal **100***b* also includes an illumination module **104***b* including the light sources **160***b* and an illumination control module **164***b*. These illumination modules are also an integral part of the IT4000 and IT4200 image engines referenced above. The portable data terminal **100***b* further includes a processor integrated circuit (IC) chip **548** such as may be provided by, for example, an INTEL Strong ARM RISC processor or an INTEL PXA255 Processor. Processor IC chip **548** includes a central processing unit (CPU) **552**. For capturing images, the processor IC chip **548** sends appropriate control and timing signals to image sensor chip **546**, as described above. The processor IC chip **548** further manages the transfer of image data generated by the chip **546** into RAM **576**. Processor IC chip **548** may be configured to partially or entirely carry out the functions of one or more of the modules, e.g., modules **104**, **108**, **112**, **116**, **120**, **124**, **128**, **132**, **134**, **136**, **140**, **144**, **150**, **152**, **165**, **168** as described in connection with FIG. **1**A.

As indicated above, the portable data terminal **100***b* may include a display **504**, such as a liquid crystal display, a keyboard **508**, a plurality of communication or radio transceivers such as a 802.11 radio communication link **556**, a Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) radio communication link **560**, and/or a Bluetooth radio communication link **564**. In additional embodiments, the portable data terminal **100***b* may also have the capacity to transmit information such as voice or data communications via Code Division Multiple Access (CDMA), Cellular Digital Packet Data (CDPD), Mobitex cellular phone and data networks and network components. In other embodiments, the portable data terminal **100***b* can transmit information using a DataTAC™ network or a wireless dial-up connection.

The portable data terminal **100***b* may further include an infrared (IR) communication link **568**. The keyboard **508** may communicate with IC chip **548** via microcontroller chip **572**. The portable data terminal **110***b* may further include RFID circuitry **578** as described above for reading or writing data to a RFID tag or token and smart card circuitry **586** including electrical contacts **590** for establishing electrical communication with a smart card such as a circuitry enabled credit card. The portable data terminal **100***b* further includes a memory **574** including a volatile memory and a non-volatile memory. The volatile memory in one embodiment is provided in part by the RAM **576**. The non-volatile memory may be provided in part by flash ROM **580**. Processor IC chip **548** is in communication with the RAM **576** and ROM **580** via a system bus **584**. Processor IC chip **548** and microcontroller chip **572** also include areas of volatile and non-volatile memory. In various embodiments where at least some of the modules discussed above, such as the elements in the control module **112**, are implemented at least in part in software, the software components can be stored in the non-volatile memories such as the ROM **580**. In one embodiment, the processor IC chip **548** includes a control circuit that itself employs the CPU **552** and memory **574**. Non-volatile areas of the memory **574** can be used, for example, to store program operating instructions.

In various embodiments, the processor IC chip **548** may include a number of I/O interfaces (not all shown in FIG. **16**) including several serial interfaces (e.g., general purpose, Ethernet, blue tooth), and parallel interfaces (e.g., PCMCIA, Compact Flash).

In one embodiment, the processor IC chip **548** processes frames of image data to, for example, decode a one or two-dimensional bar code or a set of OCR characters. Various bar code and/or OCR decoding algorithms are commercially available, such as by the incorporation of an IT4250 image engine with decoder board, available from Hand Held Products, Inc. In one embodiment, the decoder board decodes symbologies such as UPC/EAN, Code 11, Code 39, Code 128, Codabar, Interleaved 2 of 5, MSI, PDF417, MicroPDF417, Code 16K, Code 49, MaxiCode, Aztec, Aztec Mesa, Data Matrix, Qcode, QR Code, UCC Composite, Snowflake, Vericode, Dataglyphs, RSS, BC 412, Code 93, Codablock, Postnet (US), BPO4 State, Canadian 4 State, Japanese Post, KIX (Dutch Post), Planet Code, OCR A, OCR B, and the like.

Among other operations, the infrared transceiver **568** facilitates infrared copying of data from a portable data terminal **100***b* in a broadcasting mode to a portable data terminal **100***b* in a receiving mode. Utilization of infrared transceiver **568** during a data copying session allows data broadcast from a single broadcast device to be simultaneously received by several receiving devices without any of the receiving devices being physically connected to the broadcasting device.

In an additional further embodiment, the image reader **100** can be contained in a transaction terminal such as the Transaction Terminal Image Kiosk 8870 available from Hand Held Products, Inc., of 700 Visions Drive, P.O. Box 208, Skaneateles Falls, N.Y. and constructed in accordance with the invention. In a further embodiment, the image reader **100** can be contained in a fixed mount system such as the IMAGETEAM 3800E linear image engine or the IMAGETEAM 4710 two-dimensional reader available from Hand Held Products, Inc. of 700 Visions Drive, P.O. Box 208, Skaneateles Falls, N.Y.

In various embodiments, the modules discussed above including the illumination module **104**, the image collection module **108**, the control module **112**, the memory module **116**, the I/O module **120**, the actuation module **124**, the user feedback module **128**, the display module **132**, the user interface module **134**, the RFID module **136**, the smart card module **140**, the magnetic stripe card module **144**, the decoder module **150**, the illumination control module **164**, the power module **168**, the interface module **172**, the optics module **178**, the sensor array module **182**, the sensor array control module **186**, the global electronic shutter control module **190**, the row and column address and decode module **194**, and the read out module **198**, the rolling shutter control module **202**, and the auto-focusing module can be implemented in different combinations of software, firmware, and/or hardware.

Machine readable storage media that can be used in the invention include electronic, magnetic and/or optical storage media, such as magnetic floppy disks and hard disks, a DVD drive, a CD drive that in some embodiments can employ DVD disks, any of CD-ROM disks (i.e., read-only optical storage disks), CD-R disks (i.e., write-once, read-many optical storage disks), and CD-RW disks (i.e., rewriteable

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optical storage disks); and electronic storage media, such as RAM, ROM, EPROM, Compact Flash cards, PCMCIA cards, or alternatively SD or SDIO memory; and the electronic components (e.g., floppy disk drive, DVD drive, CD/CD-R/CD-RW drive, or Compact Flash/PCMCIA/SD adapter) that accommodate and read from and/or write to the storage media. As is known to those of skill in the machine-readable storage media arts, new media and formats for data storage are continually being devised, and any convenient, commercially available storage medium and corresponding read/write device that may become available in the future is likely to be appropriate for use, especially if it provides any of a greater storage capacity, a higher access speed, a smaller size, and a lower cost per bit of stored information. Well known older machine-readable media are also available for use under certain conditions, such as punched paper tape or cards, magnetic recording on tape or wire, optical or magnetic reading of printed characters (e.g., OCR and magnetically encoded symbols) and machine-readable symbols such as one and two-dimensional bar codes.

Those of ordinary skill will recognize that many functions of electrical and electronic apparatus can be implemented in hardware (for example, hard-wired logic), in software (for example, logic encoded in a program operating on a general purpose processor), and in firmware (for example, logic encoded in a non-volatile memory that is invoked for operation on a processor as required). The present invention contemplates the substitution of one implementation of hardware, firmware and software for another implementation of the equivalent functionality using a different one of hardware, firmware and software. To the extent that an implementation can be represented mathematically by a transfer function, that is, a specified response is generated at an output terminal for a specific excitation applied to an input terminal of a "black box" exhibiting the transfer function, any implementation of the transfer function, including any combination of hardware, firmware and software implementations of portions or segments of the transfer function, is contemplated herein.

While the present invention has been explained with reference to the structure disclosed herein, it is not confined to the details set forth and this invention is intended to cover any modifications and changes as may come within the scope and spirit of the following claims.

We claim:

1. An apparatus comprising:

a bar code decoding module that is configured to decode representations of at least a two dimensional bar code in image data captured by an image reader, the image reader further comprising:

a CMOS image sensor array comprising a plurality of pixels in a two-dimensional array, wherein the CMOS image sensor array is operable, in a global shutter mode, and wherein in the global shutter mode all or substantially all of the pixels in the image sensor array are exposed in the image sensor array in response to an exposure control timing pulse so as to enable the collection of image data in the form of at least a two dimensional bar code; and

at least one illumination light source configured to illuminate at least a portion of the bar code in response to an illumination control timing pulse, wherein the exposure control timing pulse and the illumination control timing pulse are interdependent.

2. The apparatus of claim **1**, wherein the bar code decoding module is further configured to select a decoding algorithm for decoding the representation of the bar code from a plurality of decoding algorithms each configured to decode a different one dimensional bar code or a two dimensional bar code.

3. The apparatus of claim **1**, wherein the at least one illumination light source is configured to project a two-dimensional observable illumination pattern over the target.

4. The apparatus of claim **1**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse.

5. The apparatus of claim **1**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse and is configured to be deactivated during another portion of the exposure control timing pulse.

6. The apparatus of claim **1**, wherein the bar code decoding module further comprises:

a classifier module that is configured to determine whether the image data comprises a one dimensional bar code or a two dimensional bar code.

7. The apparatus of claim **1**, wherein the bar code decoding module is further configured to at least decode two or more of a one dimensional universal product code bar code, a two dimensional PDF417 bar code or a bar code having abutting bar code symbols.

8. The apparatus of claim **1**, wherein the at least one illumination light source is configured to be substantially bright and the exposure control timing pulse is configured to be substantially short so as to enable the image data to be substantially non-distorted.

9. The apparatus of claim **1**, wherein the barcode decoding module further comprises:

a read out module configured to read out a set of digital values corresponding to incident light on a plurality of pixels of the CMOS image sensor array simultaneously exposed to capture the image data, a frame of image data comprises a plurality of pixel values, wherein the read out module is controlled by a read out timing control pulse.

10. The apparatus of claim **1**, further comprising:

a lens driver module, wherein the lens sensor driver module has a plurality of discrete settings, each discrete setting being configured to cause the image data to be collected by the CMOS image sensor for objects located at a particular distance from the image reader.

11. The apparatus of claim **1**, further comprising:

an auto-focusing module configured to read the image data from one or more exposed rows such that the image data is analyzed by a focusing algorithm operable to determine an auto-focus setting, the auto-focusing module configured to move a lens according to the auto-focus setting.

12. The apparatus of claim **1**, wherein the apparatus comprises one or more of a magnetic stripe reader, a biometric reader, a printer, a radio-frequency identification tag reader, a radio-frequency payment reader, or a smart card reader.

13. The apparatus of claim **1**, wherein the barcode decoding module is further configured to perform feature extraction such that a quiet zone is identifiable in the image data.

14. The apparatus of claim **1**, wherein the barcode decoding is further configured to perform feature extraction such that a finder pattern is identifiable in the image data.

15. The apparatus of claim **1**, wherein the illumination control timing pulse occurs in response to the exposure control timing pulse.

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16. The apparatus of claim **1**, wherein the exposure control timing pulse occurs in response to the illumination control timing pulse.

17. The apparatus of claim **1**, wherein a read out control timing pulse begins at the conclusion of the illumination control timing pulse.

18. The apparatus of claim **1**, wherein a read out control timing pulse begins at the conclusion of the exposure control timing pulse.

19. The apparatus of claim **1**, wherein the at least one illumination light source is configured to operate at a peak power level during at least a portion of the exposure control timing pulse in accordance with a power budget.

20. The apparatus of claim **1**, wherein the CMOS image sensor array comprises at least 640×480 active pixels.

21. The apparatus of claim **1**, wherein the CMOS image sensor array comprises an infrared filter.

22. An apparatus comprising:

a bar code decoding module that is configured to decode representations of at least a two dimensional bar code in grey level image data captured by an image reader, the image reader further comprising:

a CMOS image sensor array comprising a plurality of pixels in a two-dimensional array, wherein the CMOS image sensor array is operable in a global shutter mode, and wherein in the global shutter mode all or substantially all of the pixels in the image sensor array are exposed in the image sensor array in response to an exposure control timing pulse so as to enable the collection of image data in the form of at least the two dimensional bar code; and

at least one illumination light source configured to illuminate at least a portion of the bar code in response to an illumination control timing pulse, wherein the exposure control timing pulse and the illumination control timing pulse are interdependent.

23. The apparatus of claim **22**, wherein the bar code decoding module is further configured to select a decoding algorithm for decoding the representation of the bar code from a plurality of decoding algorithms each configured to decode a different one dimensional bar code or a two dimensional bar code.

24. The apparatus of claim **22**, wherein the at least one illumination light source is configured to project a two-dimensional observable illumination pattern over the target.

25. The apparatus of claim **22**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse.

26. The apparatus of claim **22**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse and is configured to be deactivated during another portion of the exposure control timing pulse.

27. The apparatus of claim **22**, wherein the bar code decoding module further comprises:

a classifier module that is configured to determine whether the grey level image data comprises a one dimensional bar code or a two dimensional bar code.

28. The apparatus of claim **22**, wherein the bar code decoding module is further configured to at least decode two or more of a one dimensional universal product code bar code, a two dimensional PDF417 bar code or a bar code having abutting bar code symbols.

29. The apparatus of claim **22**, wherein the at least one illumination light source is configured to be substantially bright and the exposure control timing pulse is configured to be substantially short so as to enable the grey level image data to be substantially non-distorted.

30. The apparatus of claim **22**, wherein the barcode decoding module further comprises:

a read out module configured to read out a set of digital values corresponding to incident light on a plurality of pixels of the CMOS image sensor array simultaneously exposed to capture the grey level image data, a frame of grey level image data comprises a plurality of pixel values, wherein the read out module is controlled by a read out timing control pulse.

31. The apparatus of claim **22**, further comprising:

a lens driver module, wherein the lens sensor driver module has a plurality of discrete settings, each discrete setting being configured to cause the grey level image data to be collected by the CMOS image sensor for objects located at a particular distance from the image reader.

32. The apparatus of claim **22**, further comprising:

an auto-focusing module configured to read the grey level image data from one or more exposed rows such that the grey level image data is analyzed by a focusing algorithm operable to determine an auto-focus setting, the auto-focusing module configured to move a lens according to the auto-focus setting.

33. The apparatus of claim **22**, wherein the apparatus comprises one or more of a magnetic stripe reader, a biometric reader, a printer, a radio-frequency identification tag reader, a radio-frequency payment reader, or a smart card reader.

34. The apparatus of claim **22**, wherein the barcode decoding module is further configured to perform feature extraction such that a quiet zone is identifiable in the grey level image data.

35. The apparatus of claim **22**, wherein the barcode decoding is further configured to perform feature extraction such that a finder pattern is identifiable in the grey level image data.

36. The apparatus of claim **22**, wherein the illumination control timing pulse occurs in response to the exposure control timing pulse.

37. The apparatus of claim **22**, wherein the exposure control timing pulse occurs in response to the illumination control timing pulse.

38. The apparatus of claim **22**, wherein a read out control timing pulse begins at the conclusion of the illumination control timing pulse.

39. The apparatus of claim **22**, wherein a read out control timing pulse begins at the conclusion of the exposure control timing pulse.

40. The apparatus of claim **22**, wherein the at least one illumination light source is configured to operate at a peak power level during at least a portion of the exposure control timing pulse in accordance with a power budget.

41. The apparatus of claim **22**, wherein the CMOS image sensor array comprises at least 640×480 active pixels.

42. The apparatus of claim **22**, wherein the CMOS image sensor array comprises an infrared filter.

43. An apparatus comprising:

a bar code decoding module that is configured to decode representations of at least a two dimensional bar code in grey level image data captured by an image reader, the image reader further comprising:

a CMOS image sensor array comprising a plurality of pixels in a two-dimensional array, wherein the CMOS image sensor array is configured such that all

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or substantially all of the pixels in the image sensor array are exposed in the image sensor array during the duration of the exposure control timing pulse so as to enable the collection of image data in the form of at least the two dimensional bar code, wherein the exposure control timing pulse has a duration of less than 3.7 milliseconds; and

at least one illumination light source configured to illuminate at least a portion of the bar code in response to an illumination control timing pulse, wherein the exposure control timing pulse and the illumination control timing pulse are interdependent.

44. The apparatus of claim **43**, wherein the bar code decoding module is further configured to select a decoding algorithm for decoding the representation of the bar code from a plurality of decoding algorithms each configured to decode a different one dimensional bar code or a two dimensional bar code.

45. The apparatus of claim **43**, wherein the at least one illumination light source is configured to project a two-dimensional observable illumination pattern over the target.

46. The apparatus of claim **43**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse.

47. The apparatus of claim **43**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse and is configured to be deactivated during another portion of the exposure control timing pulse.

48. The apparatus of claim **43**, wherein the bar code decoding module further comprises:

a classifier module that is configured to determine whether the grey level image data comprises a one dimensional bar code or a two dimensional bar code.

49. The apparatus of claim **43**, wherein the bar code decoding module is further configured to at least decode two or more of a one dimensional universal product code bar code, a two dimensional PDF417 bar code or a bar code having abutting bar code symbols.

50. The apparatus of claim **43**, wherein the at least one illumination light source is configured to be substantially bright and the exposure control timing pulse is configured to be substantially short so as to enable the grey level image data to be substantially non-distorted.

51. The apparatus of claim **43**, wherein the barcode decoding module further comprises:

a read out module configured to read out a set of digital values corresponding to incident light on a plurality of pixels of the CMOS image sensor array simultaneously exposed to capture the grey level image data, a frame of grey level image data comprises a plurality of pixel values, wherein the read out module is controlled by a read out timing control pulse.

52. The apparatus of claim **43**, further comprising:

a lens driver module, wherein the lens sensor driver module has a plurality of discrete settings, each discrete setting being configured to cause the grey level image data to be collected by the CMOS image sensor for objects located at a particular distance from the image reader.

53. The apparatus of claim **43**, further comprising:

an auto-focusing module configured to read the grey level image data from one or more exposed rows such that the grey level image data is analyzed by a focusing algorithm operable to determine an auto-focus setting, the auto-focusing module configured to move a lens according to the auto-focus setting.

54. The apparatus of claim **43**, wherein the apparatus comprises one or more of a magnetic stripe reader, a biometric reader, a printer, a radio-frequency identification tag reader, a radio-frequency payment reader, or a smart card reader.

55. The apparatus of claim **43**, wherein the barcode decoding module is further configured to perform feature extraction such that a quiet zone is identifiable in the grey level image data.

56. The apparatus of claim **43**, wherein the barcode decoding is further configured to perform feature extraction such that a finder pattern is identifiable in the grey level image data.

57. The apparatus of claim **43**, wherein the illumination control timing pulse occurs in response to the exposure control timing pulse.

58. The apparatus of claim **43**, wherein the exposure control timing pulse occurs in response to the illumination control timing pulse.

59. The apparatus of claim **43**, wherein a read out control timing pulse begins at the conclusion of the illumination control timing pulse.

60. The apparatus of claim **43**, wherein a read out control timing pulse begins at the conclusion of the exposure control timing pulse.

61. The apparatus of claim **43**, wherein the at least one illumination light source is configured to operate at a peak power level during at least a portion of the exposure control timing pulse in accordance with a power budget.

62. The apparatus of claim **43**, wherein the CMOS image sensor array comprises at least 640×480 active pixels.

63. The apparatus of claim **43**, wherein the CMOS image sensor array comprises an infrared filter.

64. An apparatus comprising:

a bar code decoding module that is configured to decode representations of at least a two dimensional bar code in a grey level image captured by an image reader that is configured to operate a CMOS image sensor array operable in a global shutter mode to capture a substantially distortion free image, the image reader further comprising:

the CMOS image sensor array comprising a plurality of pixels in a two-dimensional array, wherein the CMOS image sensor array is operable in the global shutter mode such that all or substantially all of the pixels in the image sensor array are exposed in the image sensor array in response to an exposure control timing pulse so as to enable the collection of image data in the form of at least the two dimensional bar code;

at least one illumination light source configured to illuminate at least a portion of the bar code in response to an illumination control timing pulse, wherein the exposure control timing pulse and the illumination control timing pulse are interdependent; and

an autodiscrimination module configured to search the captured grey level image for one or more markers, wherein in an instance in which at least one marker of the one or more markers is detected, the bar code decoding module that is configured to decode the captured grey level image in accordance with a decoding algorithm associated with the at least one marker.

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65. The apparatus of claim **64**, wherein the bar code decoding module is further configured to select a decoding algorithm for decoding the representation of the bar code from a plurality of decoding algorithms each configured to decode a different one dimensional bar code or a two dimensional bar code.

66. The apparatus of claim **64**, wherein the at least one illumination light source is configured to project a two-dimensional observable illumination pattern over the target.

67. The apparatus of claim **64**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse.

68. The apparatus of claim **64**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse and is configured to be deactivated during another portion of the exposure control timing pulse.

69. The apparatus of claim **64**, wherein the bar code decoding module further comprises:

a classifier module that is configured to determine whether the grey level image data comprises a one dimensional bar code or a two dimensional bar code.

70. The apparatus of claim **64**, wherein the bar code decoding module is further configured to at least decode two or more of a one dimensional universal product code bar code, a two dimensional PDF417 bar code or a bar code having abutting bar code symbols.

71. The apparatus of claim **64**, wherein the at least one illumination light source is configured to be substantially bright and the exposure control timing pulse is configured to be substantially short so as to enable the grey level image data to be substantially non-distorted.

72. The apparatus of claim **64**, wherein the barcode decoding module further comprises:

a read out module configured to read out a set of digital values corresponding to incident light on a plurality of pixels of the CMOS image sensor array simultaneously exposed to capture the grey level image data, a frame of grey level image data comprises a plurality of pixel values, wherein the read out module is controlled by a read out timing control pulse.

73. The apparatus of claim **64**, further comprising:

a lens driver module, wherein the lens sensor driver module has a plurality of discrete settings, each discrete setting being configured to cause the grey level image data to be collected by the CMOS image sensor for objects located at a particular distance from the image reader.

74. The apparatus of claim **64**, further comprising:

an auto-focusing module configured to read the grey level image data from one or more exposed rows such that the grey level image data is analyzed by a focusing algorithm operable to determine an auto-focus setting, the auto-focusing module configured to move a lens according to the auto-focus setting.

75. The apparatus of claim **64**, wherein the apparatus comprises one or more of a magnetic stripe reader, a biometric reader, a printer, a radio-frequency identification tag reader, a radio-frequency payment reader, or a smart card reader.

76. The apparatus of claim **64**, wherein the barcode decoding module is further configured to perform feature extraction such that a quiet zone is identifiable in the grey level image data.

77. The apparatus of claim **64**, wherein the barcode decoding is further configured to perform feature extraction such that a finder pattern is identifiable in the grey level image data.

78. The apparatus of claim **64**, wherein the illumination control timing pulse occurs in response to the exposure control timing pulse.

79. The apparatus of claim **64**, wherein the exposure control timing pulse occurs in response to the illumination control timing pulse.

80. The apparatus of claim **64**, wherein a read out control timing pulse begins at the conclusion of the illumination control timing pulse.

81. The apparatus of claim **64**, wherein a read out control timing pulse begins at the conclusion of the exposure control timing pulse.

82. The apparatus of claim **64**, wherein the at least one illumination light source is configured to operate at a peak power level during at least a portion of the exposure control timing pulse in accordance with a power budget.

83. The apparatus of claim **64**, wherein the CMOS image sensor array comprises at least 640×480 active pixels.

84. The apparatus of claim **64**, wherein the CMOS image sensor array comprises an infrared filter.

85. An apparatus comprising:

a bar code decoding module that is configured to decode representations of at least a two dimensional bar code in image data captured by an image reader that is configured to operate in a global shutter mode to capture a substantially distortion free image, the image reader further comprising:

the CMOS image sensor array comprising a plurality of pixels in a two-dimensional array, wherein the CMOS image sensor array is operable in the global shutter mode such that all or substantially all of the pixels in the image sensor array are exposed in the image sensor array in response to an exposure control timing pulse so as to enable the collection of image data in the form of at least a two dimensional bar code;

at least one illumination light source configured to illuminate at least a portion of the bar code in response to an illumination control timing pulse, wherein the exposure control timing pulse and the illumination control timing pulse are interdependent;

a binarizer module that is configured to binarize the image data to create a binarized image according to at least one of local thresholding or target image size normalization; and

an autodiscrimination module configured to search the binarized image for one or more markers, wherein in an instance in which at least one marker of the one or more markers is detected, the bar code decoding module that is configured to decode the binarized image in accordance with a decoding algorithm associated with the at least one marker.

86. The apparatus of claim **85**, wherein the bar code decoding module is further configured to select a decoding algorithm for decoding the representation of the bar code from a plurality of decoding algorithms each configured to decode a different one dimensional bar code or a two dimensional bar code.

87. The apparatus of claim **85**, wherein the at least one illumination light source is configured to project a two-dimensional observable illumination pattern over the target.

88. The apparatus of claim **85**, wherein the at least one illumination light source is configured to operate at a sub-

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stantially peak power level during at least a portion of the exposure control timing pulse.

89. The apparatus of claim **85**, wherein the at least one illumination light source is configured to operate at a substantially peak power level during at least a portion of the exposure control timing pulse and is configured to be deactivated during another portion of the exposure control timing pulse.

90. The apparatus of claim **85**, wherein the bar code decoding module further comprises:

a classifier module that is configured to determine whether the image data comprises a one dimensional bar code or a two dimensional bar code.

91. The apparatus of claim **85**, wherein the bar code decoding module is further configured to at least decode two or more of a one dimensional universal product code bar code, a two dimensional PDF417 bar code or a bar code having abutting bar code symbols.

92. The apparatus of claim **85**, wherein the at least one illumination light source is configured to be substantially bright and the exposure control timing pulse is configured to be substantially short so as to enable the image data to be substantially non-distorted.

93. The apparatus of claim **85**, wherein the barcode decoding module further comprises:

a read out module configured to read out a set of digital values corresponding to incident light on a plurality of pixels of the CMOS image sensor array simultaneously exposed to capture the image data, a frame of image data comprises a plurality of pixel values, wherein the read out module is controlled by a read out timing control pulse.

94. The apparatus of claim **85**, further comprising:

a lens driver module, wherein the lens sensor driver module has a plurality of discrete settings, each discrete setting being configured to cause the image data to be collected by the CMOS image sensor for objects located at a particular distance from the image reader.

95. The apparatus of claim **85**, further comprising:

an auto-focusing module configured to read the image data from one or more exposed rows such that the image data is analyzed by a focusing algorithm operable to determine an auto-focus setting, the auto-focusing module configured to move a lens according to the auto-focus setting.

96. The apparatus of claim **85**, wherein the apparatus comprises one or more of a magnetic stripe reader, a biometric reader, a printer, a radio-frequency identification tag reader, a radio-frequency payment reader, or a smart card reader.

97. The apparatus of claim **85**, wherein the barcode decoding module is further configured to perform feature extraction such that a quiet zone is identifiable in the image data.

98. The apparatus of claim **85**, wherein the barcode decoding is further configured to perform feature extraction such that a finder pattern is identifiable in the image data.

99. The apparatus of claim **85**, wherein the illumination control timing pulse occurs in response to the exposure control timing pulse.

100. The apparatus of claim **85**, wherein the exposure control timing pulse occurs in response to the illumination control timing pulse.

101. The apparatus of claim **85**, wherein a read out control timing pulse begins at the conclusion of the illumination control timing pulse.

102. The apparatus of claim **85**, wherein a read out control timing pulse begins at the conclusion of the exposure control timing pulse.

103. The apparatus of claim **85**, wherein the at least one illumination light source is configured to operate at a peak power level during at least a portion of the exposure control timing pulse in accordance with a power budget.

104. The apparatus of claim **85**, wherein the CMOS image sensor array comprises at least 640×480 active pixels.

105. The apparatus of claim **85**, wherein the CMOS image sensor array comprises an infrared filter.

106. The apparatus of claim **85**, wherein the binarizer module is further configured to reduce multi-pixel thick line segments in the image data into at least one single pixel thick line.

107. The apparatus of claim **85**, wherein the image data is grey level image data.

* * * * *

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(12) **United States Patent**
Kubo et al.

(10) **Patent No.: US 10,140,490 B2**
(45) **Date of Patent: Nov. 27, 2018**

(54) **MODULE FOR OPTICAL INFORMATION READER**

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(72) Inventors: **Wataru Kubo**, Warabi (JP); **Satoshi Komi**, Warabi (JP)

(73) Assignee: **OPTOELECTRONICS CO., LTD.**, Warabi-shi (JP)

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G02B 26/10 (2006.01)
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CPC ***G06K 7/10831*** (2013.01); ***G02B 7/025*** (2013.01); ***G02B 7/04*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G02B 26/105; G02B 7/023; G02B 7/025; G02B 27/30; G02B 27/62; G06K 7/1098; G06K 7/10831
See application file for complete search history.

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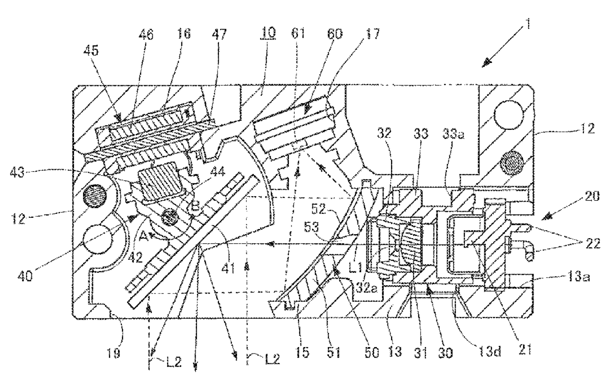
Primary Examiner — Christopher Stanford
(74) *Attorney, Agent, or Firm* — Westerman, Hattori, Daniels & Adrian, LLP

(57) **ABSTRACT**

A collimator lens unit in which an aperture limit stop formation member and a collimator lens are integrally disposed in a cylindrical member is inserted in a lens-barrel hole of the module casing so as to be reciprocatable in an optical axis direction, and a light-emitting unit is fixed in the lens-barrel hole, with an optical axis of a light source aligned with an optical axis of the collimator lens. A long hole through which an adjust pin is penetrated so as to be reciprocatable in the optical axis direction is formed in a peripheral sidewall of the lens-barrel hole, and a fitting portion in which the adjust pin is fit is formed in an outer peripheral surface of the cylindrical member. On an inner peripheral surface of the lens-barrel hole, at a position opposed to the fitting portion, bearing portions in contact with the outer peripheral surface of the cylindrical member are formed.

8 Claims, 6 Drawing Sheets



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G02B 27/30 (2006.01)
G02B 7/04 (2006.01)
G02B 7/02 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 26/105*** (2013.01); ***G02B 27/30*** (2013.01); ***G06K 7/1098*** (2013.01)

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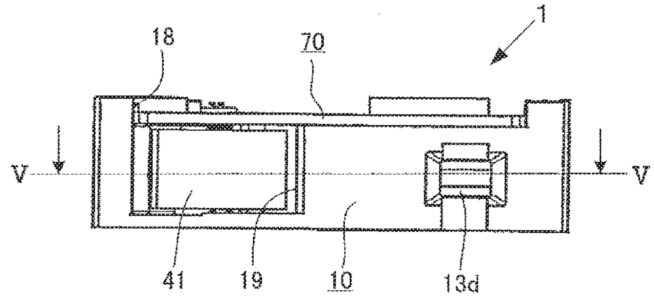
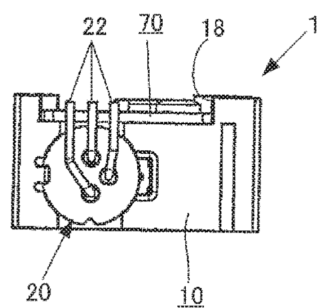
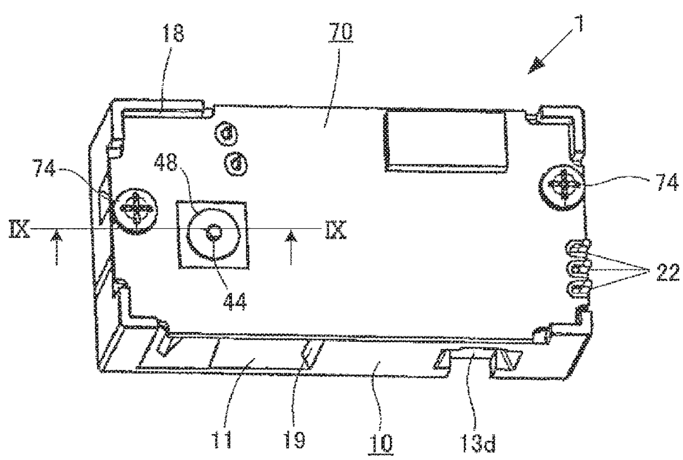
[Fig. 1]



[Fig. 2]



[Fig. 3]



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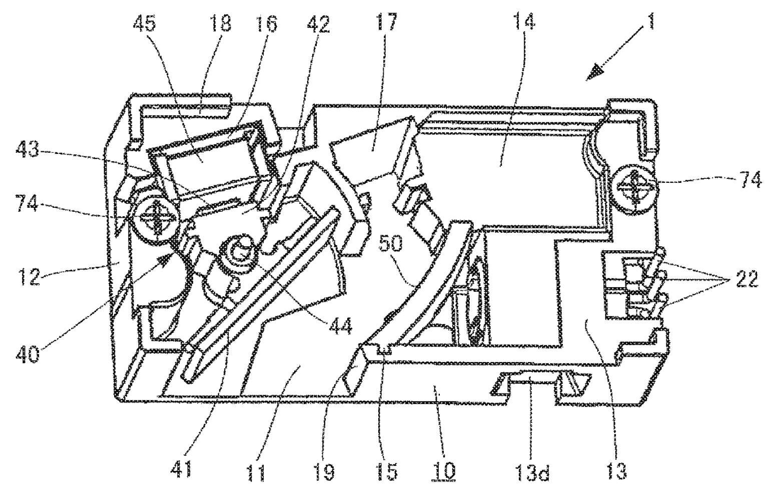
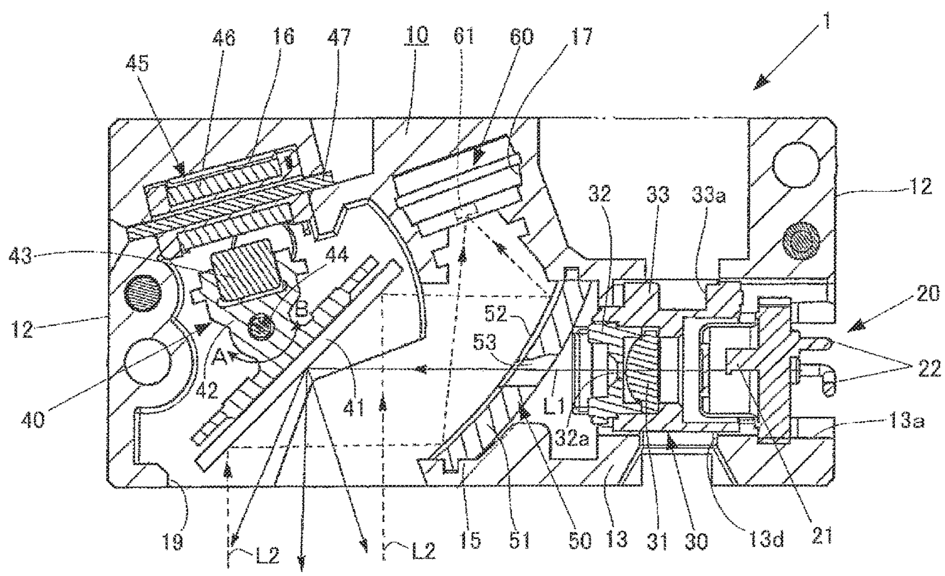
[Fig. 4]



[Fig. 5]



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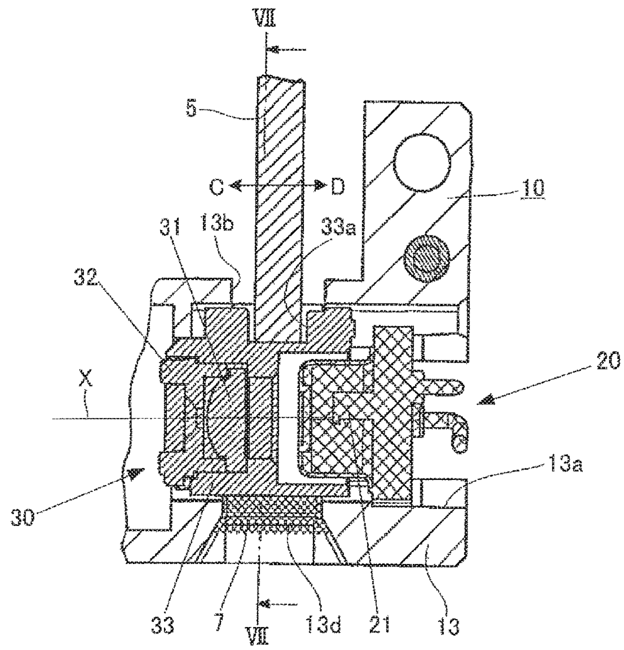
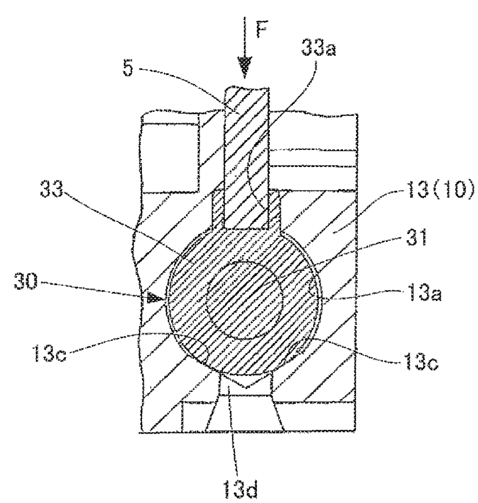
[Fig. 6]



[Fig. 7]



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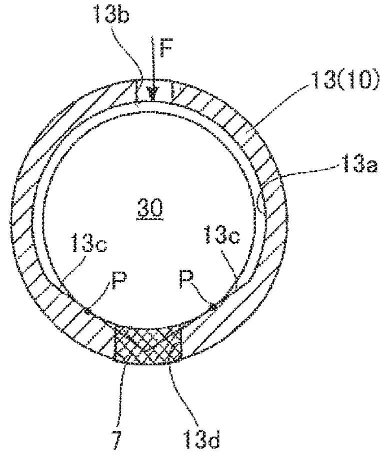
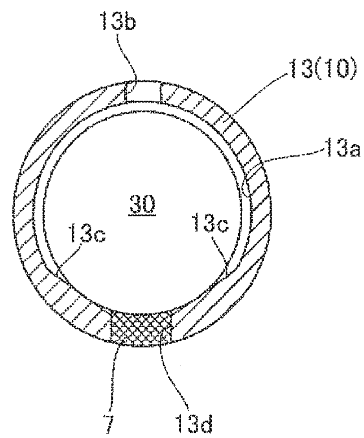
[Fig. 8A]



[Fig. 8B]



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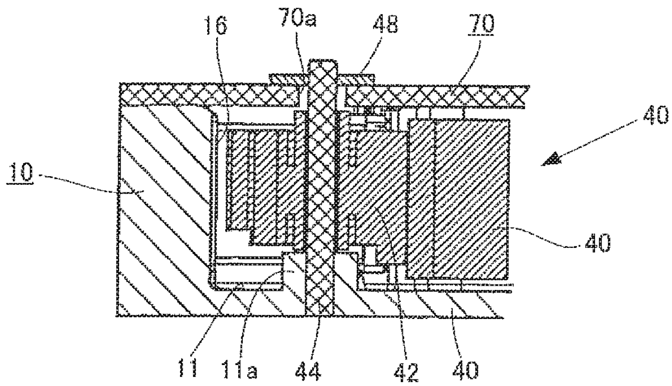
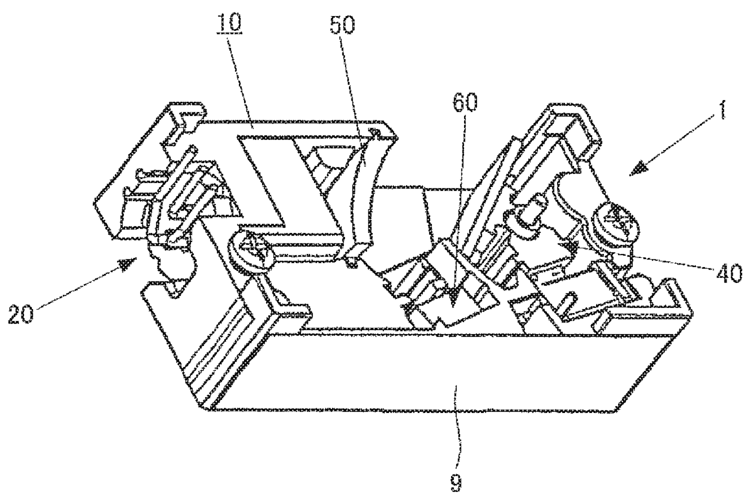
[Fig. 9]



[Fig. 10]



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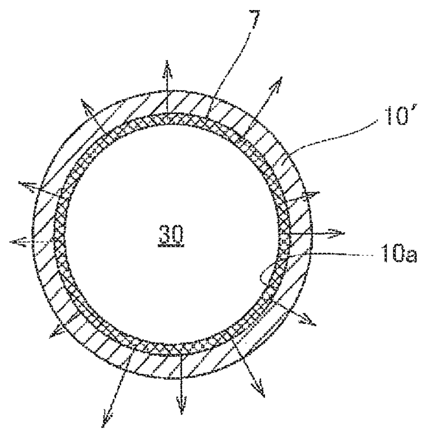
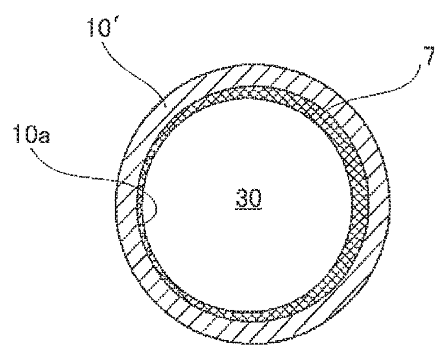
[Fig. 11A]

PRIOR ART



[Fig. 11B]

PRIOR ART



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MODULE FOR OPTICAL INFORMATION READER

FIELD OF THE INVENTION

The invention relates to a module installed in an optical information reader for reading optical information of a bar code and the like.

BACKGROUND OF THE INVENTION

As an optical information reader, bar code readers which read optical information of bar codes, two-dimensional codes, and the like indicating information such as names and prices of products are used widely by the distribution industry and the retail industry.

The bar code readers are roughly classified into hand-held ones held by one hand when in use and stationary ones, and the hand-held ones further include a pen type, a touch type, and a light beam scanning type (laser type). Among these, an optical information reader being an object of the invention. is an optical information reader such as a hand-held bar code reader of the light beam scanning type.

A bar code reader of the light beam scanning type shapes light emitted by a light source such as a laser diode (semiconductor laser) into a beam, deflects the light beam by a mirror so that the light beam hits on a bar code, and while rotating or vibrating (swinging) the mirror, scans the bar code so that the light beam moves across the bar code.

Then, the reflected light from the bar code is condensed, is received by a light-receiving sensor, and is converted to an electrical signal. The electrical signal is coded after A/D conversion and the resultant is output as bar code read information. In the hand-held optical information reader of the light beam scanning type, its read engine part is required to be greatly reduced in size and weight.

Under such circumstances, there has come into use a module for an optical information reader in which the aforesaid light source, a collimator lens for shaping the light emitted by the light source into a beam, a vibration mirror and it's driver, a collector mirror or a condenser lens, a light-receiving sensor, a processing circuit for a detection signal of the light-receiving sensor, and so on are assembled in a common easing to be modularized, as described in, for example, PLT 1, 2, 3, and so on.

In such a module for an optical information reader, a light-emitting unit whose light source is, for example, a laser diode, the collimator lens for turning the light emitted by the light source into a parallel luminous flux, and a member having an aperture through which the parallel luminous flux exits as a thin beam need to be fixedly positioned in a lens barrel, with their optical axes aligned. Further, in order for the collimator lens to surely generate the light beam which is to be converged in the parallel light flux or at a finite distance, it is necessary to accurately adjust the distance between the light-emitting unit and the collimator lens (collimation adjustment or focus adjustment) so that a focal point of the collimator lens and a light-emitting point of the light-emitting unit have a predetermined positional relation.

Therefore, in a light beam generating part in the module for the optical information reader disclosed in the aforesaid PLT 1, 2, 3, in part of the module casing, a lens-barrel hole is provided, at whose leading end portion the aperture being an aperture limit stop for letting the light beam exit therethrough is formed and whose rear end portion is opened to be formed as a press-fitting portion where to press-fit the light-emitting unit. Then, the collimator lens is bonded and

fixed at a position short of the aperture, at a leading end rear side portion of the lens-barrel hole, and the light-emitting unit is pressed into the press-fitting portion from the rear end portion, whereby they are positioned.

CITATION LIST

Patent Literature

{PTL 1} U.S. Pat. No. 7,206,109 B2
{PTL 2} WO 03/019463 A1
{PTL 3} JP 2003-76942 A

SUMMARY OF INVENTION

Technical Problem

Such a conventional module for an optical information reader had the following problems.

Since the light-emitting unit is pushed into the lens-barrel hole while being pressed, and for the collimation adjustment, it is moved in one direction (a direction which is an optical axis direction and in which it approaches the collimator lens), re-adjustment by returning it was not possible. Accordingly, when the light-emitting unit is pushed too much, this module becomes a defective product, resulting in worsened production yields.

Further, delicate adjustment on a micron level was not possible since the light-emitting unit is press-fit and thus frictional resistance is high, and there is a possibility that the collimator lens and the laser diode are tilted relatively to each other.

Object of the Invention

The invention was made in consideration of the above technical background, and has an object to make it possible to, in a module for an optical information reader, easily and delicately make collimation adjustment and focus adjustment in both directions of back and forth directions along an optical axis while preventing a collimator lens and a laser diode from being tilted relatively to each other, thereby greatly reducing the occurrence of defective products to enhance production yields.

Solution to Problem

A module for an optical information reader according to the invention is a module for an optical information reader in which a light-emitting unit having a light source such as a laser diode, a collimator lens, a vibration mirror for scanning, a collector mirror or a condenser lens, and a light-receiving sensor are disposed in a module casing to be modularized, and it is structured as follows in order to achieve the aforesaid object.

A collimator lens unit in which an aperture limit stop formation member and the collimator lens are integrally disposed in a cylindrical member is inserted in a lens-barrel hole of the module casing so as to be reciprocatable in an optical axis direction within a predetermined range, and the light-emitting unit is fixed to the module easing in the lens-barrel hole, with an optical axis of the light source aligned with an optical axis of the collimator lens.

Further, a long hole through which an adjust pin is penetrated so as to be reciprocatable in the optical axis direction within a predetermined range is formed in a peripheral sidewall of the lens-barrel hole of the module

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casing, and a fitting portion in which a tip portion of the adjust pin penetrating through the long hole is fit is formed in an outer peripheral surface of the cylindrical member.

Furthermore, on an inner peripheral surface of the lens-barrel hole of the module casing, at or near a position opposed to the fitting portion, bearing portions in contact with the outer peripheral surface of the cylindrical member are formed at positions symmetrical with respect to the position in terms of an inner circumferential direction of the lens-barrel hole.

Preferably, the bearing portions form a V-shaped slope by two flat surfaces which, in a circumferential direction, are in point contact with the outer peripheral surface of the cylindrical member, and in an axial direction, are in line contact with the outer peripheral surface.

Preferably, an open-hole through which an adhesive for fixing the cylindrical member is tillable is formed in a middle region, of the V-shaped slope, which is not in contact with the outer peripheral surface of the cylindrical member.

The collimator lens unit may be structured such that the collimator lens and the aperture limit stop formation member are fixed to the cylindrical member.

The collimator lens unit may be structured such that the aperture limit stop formation member and the cylindrical member are integrally disposed on the collimator lens itself.

The collimator lens unit may be structured such that the collimator lens and the cylindrical member are integrally formed of the same material or different kinds of materials, and to the resultant formed body, the aperture limit stop formation member is fixed.

The module casing may be formed of resin. Desirably, the resin is reinforced resin in which carbon is dispersed.

Desirably, a metallic foil is affixed on an outer wall surface of the module casing made of the resin, at least near a portion where the light-receiving sensor is housed.

Advantageous Effects of Invention

In the module for the optical information reader according to the invention, the module casing is fixed to a jig, the tip portion of the adjust pin is passed through the long hole of the module casing to be inserted into the lens-barrel hole and is fit in the fitting portion of the cylindrical member or the cylindrical part of the collimator lens unit, and when the adjust pin is moved in the optical axis direction of the collimator lens by a linear movement mechanism of the jig, it is possible to move the collimator lens integrally with the cylindrical member or the cylindrical part to easily make collimation adjustment.

Further, the adjustment can be made while the collimator lens is moved in the both directions of the optical axis direction, that is, directions in which it approaches and separates from the light source, and therefore, if it is moved too much in one of the directions, the re-adjustment is possible by returning it. This can greatly reduce the occurrence of defective products to enhance production yields. Setting a movement pitch of the adjust pin fine can facilitate, even delicate and highly accurate adjustment.

Since it is possible for the adjust pin to move the cylindrical member or the cylindrical part of the collimator lens unit while pressing it against the bearing portions on the opposite side, the adjustment can be made without any deviation of the optical axis. Further, by reducing a contact area between the outer peripheral surface of the cylindrical member or the cylindrical part and the bearing portions, it is possible to move the cylindrical member or the cylindrical part smoothly with a relatively small force.

If the open-hole from which the adhesive can be filled is formed near the bearing portions, it is possible to fill the adhesive from the opening to fixedly bond the cylindrical member or the cylindrical part to the module casing after the collimation adjustment while pressing the cylindrical member or the cylindrical part against the bearing portions by the adjust pin, and thus adjustment deviation and optical axis deviation of the collimator lens are not liable to occur.

Forming the module casing of the resin having the heat dissipation property and the shielding property makes it possible to reduce weight as well as to reduce cost far more than forming it of metal. In addition, the heat dissipation property and the shielding property to a degree not practically problematic can also be obtained. Using the black resin such as the reinforced resin in which carbon is dispersed makes it possible to prevent the reflection of the light. If the shielding effect is not sufficient, by affixing the metallic foil on a necessary portion of the outer wall surface of the module casing, it is possible to enhance the shielding effect.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a front view of one embodiment of a module for an optical information reader according to the invention.

FIG. **2** is a right side view of the module for the optical information reader according to the same.

FIG. **3** is a perspective view of the module for the optical information reader according to the same seen from obliquely above.

FIG. **4** is a perspective view of the module for the optical information reader according to the same seen from the same direction as that in FIG. **3**, with a circuit board removed.

FIG. **5** is an enlarged sectional view taken along V-V line in FIG. **1**.

FIG. **6** is an enlarged partial sectional view illustrating a light beam generating part in FIG. **5** together with an adjust pin.

FIG. **7** is a partial sectional view taken along VII-VII line in FIG. **6**.

FIG. **8**A is a sectional view schematically illustrating a cross section similar to that in FIG. **7** to explain characteristics of collimation adjustment according to an embodiment of the invention.

FIG. **8**B is a sectional view illustrating the same in a state after an adhesive for fixing a collimator lens unit to a module casing is cured.

FIG. **9** is a sectional view taken along IX-IX line in FIG. **3**.

FIG. **10** is a perspective view illustrating an embodiment in which a metallic foil is affixed on an outer wall surface of the module casing to enhance a shielding effect, with the circuit board removed.

FIG. **11**A is a sectional view illustrating a bonding example being a reference example for comparison with the embodiment of the invention, which corresponds to FIG. **8**A before the adhesive is cured.

FIG. **11**B is a sectional view illustrating the same, which corresponds to FIG. **8**B after the adhesive is cured.

DETAILED DESCRIPTION

Hereinafter, modes for carrying out the invention will be described based on the drawings.

First, the entire structure of one embodiment of a module for an optical information reader according to the invention will be specifically described with reference to FIG. **1** to FIG. **5**.

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FIG. **1** is a front view of the module for the optical information reader and FIG. **2** is a right side view thereof FIG. **3** is a perspective view of the module for the optical information reader seen from obliquely above, and FIG. **4** is a perspective view of the same seen from the same direction, with a circuit board removed. FIG. **5** is an enlarged sectional view taken along V-V line in FIG. **1**.

This module **1** for the optical information reader is a read engine installed in an optical information reader such as a bar code reader, and as illustrated in these drawings, it is composed of a module casing **10**; a light-emitting unit **20**, a collimator lens unit **30**, a vibration mirror driver **40**, a collector mirror **50** having a concave surface shape, and a light-receiving sensor **60** which are assembled in the module casing **10**; a circuit board **70** attached to an upper surface of the module casing **10**; and so on.

The module casing **10** has, for example, a size of 14 mm depth (D) 28 mm width (W), and 7.5 mm height (H) as its whole outer shape, but this is not restrictive. Since such a module casing is required to have a heat dissipation property and a shielding property, it has been conventionally formed by a die casting manufacturing method by using metal such as, for example, zinc called ZDC2 or a magnesium alloy called AZ91D. The module casing of the module for the optical information reader according to the invention may similarly be formed of metal by the die casting manufacturing method.

However, the module casing **10** in this embodiment is formed of resin higher in heat dissipation property (thermal conductivity) and shielding property (electric conductivity) than ordinary resin, for example, formed of black reinforced resin in which carbon is dispersed. As a specific example of the resin material, TCF1140 manufactured by Mitsubishi Engineering-Plastics Corporation is preferably used. Forming the module casing **10** of such resin can achieve a cost reduction and a great weight reduction, and to obtain a heat dissipation property and a shielding property high enough for practical application.

Further, this module casing **10** has a bottom surface portion **11**, a sidewall portion **12** surrounding its periphery, a light beam generating part housing part **13**, a LSI housing recessed part **14**, a collector mirror attachment part **15**, a vibration mirror driver attachment part **16**, a light-receiving unit attachment part **17**, a circuit board holding part **18**, and so on.

On the bottom surface portion **11** of the vibration mirror driver attachment part **16**, a boss **11*a*** (refer to FIG. **9**) is formed, and a lower end portion of a support shaft **44** of a vibration mirror **41** is fit therein to be supported. A front face, of the sidewall portion **12**, corresponding to the vibration mirror driver attachment part **16** is opened to form an opening **19** for letting a light beam exit and incident.

As illustrated in FIG. **5**, the light-emitting unit **20** and the collimator lens unit **30** which form a light beam generating part are disposed in a lens-barrel hole **13*a*** which is formed in the light beam generating part housing part **13** of the module casing **10** and which has a cylindrical inner peripheral surface.

The light-emitting unit **20** has a laser diode **21** as a light source, and is inserted to be fixed in the lens-barrel hole **13*a*** from an opening of the sidewall portion **12** of the module casing **10** on the right side in FIG. **5**. As illustrated in FIG. **2** and so on, three terminals **22** of the laser diode **21** project to extend upward from a rear end surface of the light-emitting unit **20** and are connected to terminals of the board **70** side.

In the collimator lens unit **30**, a collimator lens **31** and an aperture limit stop formation member **32** in which an aperture **32*a*** being an aperture limit stop is formed are integrally fixed in a cylindrical member **33** being a collimator lens barrel. The aperture limit stop formation member **32** is fixed to a front end portion of the cylindrical member **33** by an adhesive or the like, presses the collimator lens **31** against an inner periphery stepped portion of the cylindrical member **33** to fix it, and has the aperture **32*a*** disposed just in front of the collimator lens **31**.

This collimator lens unit **30** is inserted in the lens-barrel hole **13*a*** of the light beam generating part housing part **13** of the module casing **10** so as to be reciprocatable in an optical axis direction within a predetermined range. The aperture limit stop formation member **32** and the cylindrical member **33** can be formed of the same material as or has performance equivalent to that of the module casing **10** (polycarbonate containing 20% glass, aluminum, or the like). The light-emitting unit **20** is fixed to the module casing **10** in the lens-barrel hole **13*a*** so as to partly enter the inside of the cylindrical member **33**, with an optical axis of the light source being aligned with an optical axis of the collimator lens **31**. Details of the collimator lens unit **30** and collimation adjustment will be described later.

As illustrated in FIG. **4** and FIG. **5**, the vibration mirror driver **40** is composed of: a vibration mirror **41** for light beam scanning made of metal, resin, or glass; a vibration mirror holding member **42** fixed to a front surface portion of the vibration mirror **41** and made of resin; a movable magnet (permanent magnet) **43** fixed to a rear surface side of the vibration mirror holding member **42**; the support shaft **44** in a pin shape supporting the vibration mirror holding member **42** so as to allow its rotation; and a coil unit **45** disposed to face and to be apart from and in parallel to the movable magnet **43**. In the coil unit **45**, a yoke **47** penetrates through a coil **46** in a direction perpendicular to a winding direction of the coil **46**.

These are attached to the vibration mirror driver attachment part **16** of the module casing **10**. Then, by an action of the movable magnet **43** and the coil unit **45**, the vibration mirror holding member **42** and the vibration mirror **41** fixed thereto are vibrated (swung) in a seesaw manner as indicated by the arrows A, B in FIG. **5**.

A collector mirror **50** having a concave surface shape is fixed in a tilting manner to the collector mirror attachment part **15** of the module casing **10** so as to face the vibration mirror **41** and the light-receiving sensor **60**. The collector mirror **50** has a reflective film **52** formed on a concave curved surface of a curved substrate **51** made of resin, and has a rectangular or circular through hole **53** formed at its center portion to allow the light beam to pass therethrough.

The light-receiving sensor **60** has a light-receiving element **61** such as a photodiode (PD), and is integrated with the circuit board **70** with its two terminals connected to the circuit board **70** illustrated in FIG. **3**. Accordingly, when the circuit board **70** is mounted on the circuit board holding part **18** of the module casing **10**, the light-receiving sensor **60** is inserted to the light-receiving sensor attachment part **17** to be disposed at a predetermined position.

On the circuit board **70**, a not-illustrated necessary wiring pattern is formed and various kinds of chip-shaped electronic components are attached, and on its rear surface side, a LSI (large-scale integrated circuit) playing a central role in signal processing and control is mounted.

Then, this circuit board **70** is fixedly attached to the upper surface of the module casing **10** with a plurality of screws **74**, and serves also as an upper cover of this module **1** for

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the optical information reader. At this time, the LSI mounted on the rear surface is housed in the LSI housing recessed part **14** (FIG. **4**) of the module casing **10**. The LSI is prevented from being influenced by electromagnetic wave noise generated by other electronic devices, cellular phones, and so on since four surfaces of its outer periphery are surrounded by the resin with a high shielding property of the module casing **10**.

Functions of the module **1** for the optical information reader thus structured will be described by mainly using FIG. **5**.

A laser ray is generated as a result of the light emission of the laser diode **21** being the light source in the light-emitting unit **22**, this is turned into a luminous flux which is parallel or is converged at a desired distance by the collimator lens **31**, and the luminous flux is passed through the aperture **32***a* to be radiated as a laser beam L**1** indicated by the solid line.

This laser beam L**1** passes through the through hole **53** of the collector mirror **50** to reach the vibration mirror **41**, is reflected in a predetermined angular range whose center is 90°, due to the vibration of the vibration mirror **41**, and exits from the opening **19** to the outside. This laser beam irradiates a not-illustrated bar code symbol.

The bar code symbol has a plurality of black and white vertical stripes each having a predetermined width stipulated by the standard as is well known. They are called black bars and spaces. Light with different reflectance is reflected depending on a lateral width of each of the black bars and the spaces.

Rays L**2** (indicated by the broken-line arrows in FIG. **5**) reflected from the bar code symbol pass through the opening **19** again and enter the vibration mirror **41** to be reflected. Their reflected lights are collected by the collector mirror **50**. At this time, since the vibration mirror **41** vibrates due to a magnetic force generated between the coil unit **45** and the movable magnet **43**, it is possible for the lights in a wide range reflected from the bar code symbol to enter and to be sent to the collector mirror **50**. Then, the lights collected by the collector mirror **50** are all received by the light-emitting element **61** of the light-receiving sensor **60**.

The light-receiving sensor **60** outputs an electrical signal according to the intensity of the light received by the light-receiving element **61** and sends the electrical signal to the circuit board **70**. In the circuit board **70**, the electrical signal is A/D converted and thereafter the digital signal is processed, whereby data read from the bar code symbol is obtained.

By assembling this module **1** for the optical information reader in a not-illustrated case together with a power supply part and so on, it is possible to easily complete a compact optical information reader such as a hand-held bar code reader.

Next, a characterizing structure in the light beam generating part of this module **1** for the optical information reader, a method of the collimation adjustment (also called focus adjustment), and a fixing method of the collimator lens unit **30** and the module casing **10** after this adjustment will be described based on FIG. **6**, FIG. **7**, FIG. **8**A, and FIG. **8**B.

FIG. **6** is an enlarged partial sectional view illustrating the light beam generating part in FIG. **5** together with the adjust pin, and FIG. **7** is a partial sectional view taken along VII-VII line in FIG. **6**. In these drawings, the light-emitting unit **20** is entirely cross-hatched in the same manner, and the collimator lens unit **30** is also entirely hatched in the same manner.

FIG. **8**A is a sectional view schematically illustrating a cross section similar to that in FIG. **7** to explain characteristics of the collimation adjustment according to the embodiment of the invention, and FIG. **8**B is a sectional view illustrating a state after the adhesive for fixing this collimator lens unit **30** to the module casing is cured. In these drawings, the hatching of the collimator lens unit **30** is omitted.

As previously described, the collimator lens unit **30** has the collimator lens **31** and the aperture limit stop formation member **32** integrally fixed in the cylindrical member **33**, and is inserted in the lens-barrel hole **13***a* of the light beam generating part housing part **13** of the module casing **10** so as to be reciprocatable in the direction along the optical axis X within the predetermined range. Thus, an outside diameter of the cylindrical member **33** is slightly smaller than an inside diameter of the lens-barrel hole **13***a* and there exists a small gap between the both.

In a peripheral sidewall of the lens-barrel hole **13***a* in the light beam generating part housing part **113** of the module casing **10**, a long hole **131**) through which the adjust pin **5** penetrates so as to be reciprocatable in the optical axis direction (C and D directions indicated by the arrows in FIG. **6**) within a predetermined range is formed. Further, in an outer periphery of the cylindrical member **33** of the collimator lens unit **30**, a fitting portion **33***a* in which a tip portion of the adjust pin **5** penetrating through the long hole **13***b* is fit is formed. The fitting portion **33***a* is a recessed portion in this embodiment, but if a recessed portion is formed in a tip surface of the adjust pin **5**, the fitting portion of the outer periphery of the cylindrical member **33** can be a projecting portion.

On an inner peripheral surface of the lens-barrel hole **13***a* of the module casing **10**, at or near a position opposed to the fitting portion **33***a*, bearing portions **13***c* in contact with the outer peripheral surface of the cylindrical member **33** are disposed at positions symmetrical with respect to this position in terms of a circumferential direction of the lens-barrel hole **13***a*.

In this embodiment, as illustrated in FIG. **7**, the pair of bearing portions **13***c* form a V-shaped slope which is thick so as to make an inside diameter of the inner peripheral surface of the lens-barrel hole **13***a* smaller than that at the other portion of the inner peripheral surface. Accordingly, when the collimator lens unit **30** is pressed in the arrow F direction in FIG. **7** by the adjust pin **5**, the bearing portions **13***c* come into point contact with the outer peripheral surface of the cylindrical member **33** at P points illustrated in FIG. **8**A in the circumferential direction and into line contact therewith in an axial direction. In this state, the optical axis X of the collimator lens and a light emission center of the light-emitting unit **20** coincide with each other, and the collimator lens is easily movable along the optical axis X as it is.

These bearing portions **13***c* are not limited to the V-shaped slope, but the bearing portion may be a slightly inwardly projecting curved surface formed at part of the inner peripheral surface of the lens-barrel hole **13***a*, or a curved-surface projection provided along the axial direction on the inner peripheral surface.

Further, in the bearing portions **13***c* or in the vicinity thereof, in this embodiment, in a middle region, of the V-shaped slope being the pair of bearing portions **13***c*, which is not in contact with the outer peripheral surface of the cylindrical member **33**, an open-hole **13***d* through which an adhesive for fixing the cylindrical member **33** is finable is formed.

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The collimation adjustment (focus adjustment) in the light beam generating part of the module **1** for the optical information reader thus structured is performed as follows.

The module **1** for the optical information reader whose assembly is finished is fixed to a not-illustrated jig. Then, as illustrated in FIG. **6**, the tip portion of the adjust pin **5** disposed on the jig is inserted to the long hole **13***b* formed in the light beam generating part housing part **13** of the module casing **10**, and further is fit in the fitting portion **33***a* formed in the outer periphery of the cylindrical member **33** of the collimator lens unit **30**. By the adjust pin **5** being pressed in the arrow F direction illustrated in FIG. **7**, the cylindrical member **33** of the collimator lens unit **30** is pressed in the same direction, and its outer peripheral surface is brought into point contact with the pair of bearing portions **13***c* formed on the inner peripheral surface of the lens-barrel hole **13***a,* at the P points illustrated in FIG. **8**A.

When the adjust pin **5** is moved in this state in the arrow C direction or D direction illustrated M FIG. **6** by a linear feeding mechanism of the jig, the collimator lens unit **30** moves in accordance therewith along the optical axis X of the collimator lens **31**, so that its distance from the light-emitting unit **20** fixed in the lens-barrel hole **13***a* of the module casing **10** changes.

Consequently, the laser light emitted from the laser diode **21** being the light source of the light-emitting unit **20** is turned into an accurate parallel luminous flux by the collimator lens **31** of the collimator lens unit **30**, which makes it possible to perform the collimation adjustment or the focus adjustment so that the light exits as a prescribed laser beam through the aperture **32***a.*

This adjustment can be performed by moving the collimator lens unit **30** in both a direction in which it separates from the light-emitting unit **20** and a direction in which it approaches the light-emitting unit **20**, and therefore in a case where the adjustment is made excessively in one of the directions, it is possible to return it for re-adjustment, so that a defective product due to the poor collimation adjustment scarcely occurs. The adjust pin **5** can be moved by a linear motor mechanism, a fine-pitch ball screw mechanism, or the like, and delicate adjustment can be easily made.

After the collimation adjustment is thus finished, as illustrated in FIG. **8**A, while the collimator lens unit **30** is pressed in the arrow F direction by the adjust pin **5** to be pressed against the pair of bearing portions **13***c*, the adhesive **7** is filled in the open-hole **13***d* formed in the middle portion of the pair of bearing portions **13***c* in the module casing **10** and is cured.

If, for example, an ultraviolet curing adhesive is used as this adhesive **7**, it can be cured in a short time by being irradiated with ultraviolet light after being filled.

Owing to the curing of the adhesive **7**, the collimator lens unit **30** is bonded and fixed to the module casing **10** while being kept at such a predetermined position that part of its outer peripheral surface abuts on the pair of bearing portions **13***c,* and even if the pressing of the collimator lens unit **30** is released as illustrated in FIG. **8**B by pulling out the adjust pin **5**, the optical axis of the collimator lens **31** does not deviate or tilt.

Thereafter, when the adhesive is injected also from the long hole **13***b* for adjust pin insertion and is cured, it is possible to more surely fix the collimator lens unit **30** to the module casing **10**.

On the other hand, in a reference example, as illustrated in FIG. **11**A, it is assumed that an inner peripheral surface of a lens-barrel hole **10***a* of a module easing **10'** is formed as a round cylindrical surface without having bearing portions, and the adhesive **7** is filled and cured in a gap (clearance) between the inner peripheral surface and the outer peripheral surface of the collimator lens unit **30**.

In this case, as illustrated in FIG. **11**B, the collimator lens unit **30** is likely to be bonded and fixed to the lens-barrel hole **10***a* of the module casing **10'** in a state where the axis of the collimator lens unit **30**, that is, the optical axis of the built-in collimator lens is deviated from or tilted relatively to a central axis of the lens-barrel hole **10***a.*

This is because, due to the adhesive **7** filled in the clearance between the outer peripheral surface of the collimator lens unit **30** and the inner peripheral surface of the lens-barrel hole **10***a,* the collimator lens unit **30** is in a floating state in the lens-barrel hole **10***a,* and when the adhesive **7** is cured, contraction stresses are generated as illustrated by many arrows in FIG. **11**A, and due to unevenness or the like of an application amount of the adhesive, its strength differs depending on each circumferential-direction position.

Incidentally, in this embodiment, the collimator lens **31** and the aperture limit stop formation member **32** are integrally fixed to the cylindrical member **33** to form the collimator lens unit **30**, but instead, an aperture limit stop formation part and a cylindrical part may be integrally provided on the collimator lens itself to form the collimator lens unit. Further, the collimator lens and the cylindrical part may be integrally formed of the same material or different kinds of materials, and the aperture limit stop formation part may be integrally fixed to the resultant to form the collimator lens unit.

Incidentally, in the module **1** for the optical information reader of this embodiment, since the module casing **10** is formed of resin, the support shaft **44** of the vibration mirror **41** is liable to lack support strength if being supported in a cantilever manner. Here, a structure for enhancing the support strength will be described based on FIG. **3** and FIG. **9**. FIG. **9** is a sectional view taken along IX-IX line in FIG. **3**, and the vibration mirror driver **40** is entirely hatched in the same manner.

As illustrated in FIG. **9**, on the bottom surface portion **11** of the module casing **10** (including the vibration mirror driver attachment part **16**), the boss **11***a* is formed and a lower end portion of the support shaft **44** of the vibration mirror **41** is fit therein to be supported. An upper end portion of this support shaft **44** loosely penetrates through a through hole **70***a* formed in the circuit board **70** to protrude upward, and a holder disk **48** having a center hole is fit therearound as illustrated in FIG. **3** and FIG. **9** and this holder disk **48** is bonded or soldered to the upper surface of the circuit board **70** to be fixed.

With this structure, the support shaft **44** of the vibration mirror **41** is supported at two points by the bottom surface portion **11** of the module casing **10** and the circuit board **70**, which eliminates a risk of its tilting. Further, even when the support shaft **44** receives an external force such as a drop impact, a load for the bottom surface portion **11** of the module casing **10** to support the support shaft **44** is reduced.

Instead of the holder disk **48** having the center hole, a holder member in a hat shape having a recessed portion where to fit the upper end portion of the support shaft **44** and a flange portion may be used.

Next, FIG. **10** is a perspective view illustrating an embodiment in which a metallic foil is affixed on an outer wall surface of the module casing **10** to enhance a shielding effect, with the circuit board **70** removed.

In this embodiment using the photodiode (PD) as the light-receiving sensor **60**, in order to more ensure a noise

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countermeasure, a metallic foil **9** is affixed on the outer wall surface, of the above-mentioned resin module casing **10**, at least near a portion housing the light-receiving sensor **60** having the built-in photodiode as illustrated in FIG. **10**, to thereby enhance the shielding effect.

Optical information read by the optical information reader including the module for the optical information reader according to the invention is not limited to bar codes but may be various kinds of two-dimensional codes such as PDF417, a QR code, and Aztec Code.

Hitherto, the embodiments of the invention have been described, but the invention is not limited to these, and it goes without saying that, in carrying out the invention, addition and changes can be appropriately made to their structures, part of the structures may be omitted, or shapes and materials may be changed.

The structures of the above-described embodiments and modification examples can of course be carried out by being arbitrarily combined as long as they are not mutually inconsistent.

INDUSTRIAL APPLICABILITY

The module for the optical information reader according to the invention is applicable to various kinds of optical information readers such as a bar code reader.

What is claimed is:

1. A module for an optical information reader in which a light-emitting unit having a light source, a collimator lens, a vibration mirror for scanning, a collector mirror or a condenser lens, and a light-receiving sensor are disposed in a module casing to be modularized,

wherein a collimator lens unit, in which an aperture limit stop formation member and the collimator lens are integrally disposed in a cylindrical member, is inserted in a lens-barrel hole of the module casing so as to be reciprocatable in an optical axis direction within a predetermined range, and the light-emitting unit is fixed to the module casing in the lens-barrel hole, with an optical axis of the light source aligned with an optical axis of the collimator lens, and wherein the aperture limit stop formation member radiates an output laser beam,

wherein a long hole through which an adjust pin is penetrated so as to be reciprocatable in the optical axis direction within a predetermined range is formed in a peripheral sidewall of the lens-barrel hole of the module casing, and a fitting portion in which a tip portion of the adjust pin penetrating through the long hole is fit is formed in an outer peripheral surface of the cylindrical member,

wherein, on an inner peripheral surface of the lens-barrel hole of the module casing, at a position diametrically opposite from the long hole and the fitting portion, a pair of bearing portions which, in a circumferential direction, are in point contact with the outer peripheral surface of the cylindrical member, and in an axial direction, are in line contact with the outer peripheral surface are formed at positions symmetrical with respect to the position in terms of an inner circumferential direction of the lens-barrel hole,

wherein an open-hole through which an adhesive for fixing the cylindrical member is fillable is formed in a middle region of the pair of bearing portions, and

wherein the bearing portions form a V-shaped slope by two flat surfaces which, in a circumferential direction, are in point contact with the outer peripheral surface of the cylindrical member, and in an axial direction, are in line contact with the outer peripheral surface.

2. The module for the optical information reader according to claim **1**, wherein an open-hole through which an adhesive for fixing the cylindrical member is fillable is formed in a middle region, of the V-shaped slope, which is not in contact with the outer peripheral surface of the cylindrical member.

3. The module for the optical information reader according to claim **1**, wherein the collimator lens unit is structured such that the collimator lens and the aperture limit stop formation member are fixed to the cylindrical member.

4. The module for the optical information reader according to claim **1**, wherein the collimator lens unit is structured such that the aperture limit stop formation member and the cylindrical member are integrally disposed on the collimator lens itself.

5. The module for the optical information reader according to claim **1**, wherein the collimator lens unit is structured such that the collimator lens and the cylindrical member are integrally formed of the same material or different kinds of materials, and to the resultant formed body, the aperture limit stop formation member is fixed.

6. The module for the optical information reader according to claim **1**, wherein the module casing is formed of resin.

7. The module for the optical information reader according to claim **6**, wherein the resin is reinforced resin in which carbon is dispersed.

8. The module for the optical information reader according to claim **6**, wherein a metallic foil is affixed on an outer wall surface of the module casing made of the resin, at least near a portion where the light-receiving sensor is housed.

* * * * *

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US007159783B2

(12) **United States Patent**
Walczyk et al.

(10) **Patent No.: US 7,159,783 B2**
(45) **Date of Patent: Jan. 9, 2007**

(54) **CUSTOMIZABLE OPTICAL READER**

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(73) Assignee: **Hand Held Products, Inc.**, Skaneateles Falls, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/203,667**

(22) Filed: **Aug. 12, 2005**

(65) **Prior Publication Data**

US 2005/0284943 A1 Dec. 29, 2005

Related U.S. Application Data

(63) Continuation of application No. 10/402,885, filed on Mar. 28, 2003, now Pat. No. 6,959,865.

(60) Provisional application No. 60/368,375, filed on Mar. 28, 2002.

(51) **Int. Cl.**
G06K 7/10 (2006.01)

(52) **U.S. Cl.** **235/472.01**; 235/454; 235/462.15; 235/462.45; 235/472.01

(58) **Field of Classification Search** 235/472.01, 235/462.45, 462.15, 472.02
See application file for complete search history.

(56) **References Cited**

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6,899,273 B1 * 5/2005 Hussey et al. 235/462.48
2004/0256464 A1 * 12/2004 Longacre et al. 235/462.45

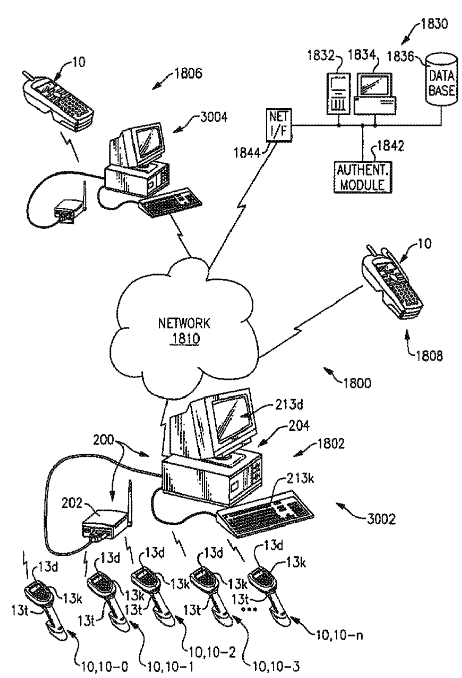
* cited by examiner

Primary Examiner—Seung Ho Lee
(74) *Attorney, Agent, or Firm*—Wall Marjama & Bilinski LLP

(57) **ABSTRACT**

An optical reader, which is operable in a “host commands” mode and a “host routines” mode. In the “host commands” mode, the reader receives and executes a script routine module from a host. In the “host routines” mode, the reader receives a script routine Module identifier from the host, and the reader, in turn, executes a selected one of a plurality of reader-stored script routine modules based on the identifier.

20 Claims, 11 Drawing Sheets



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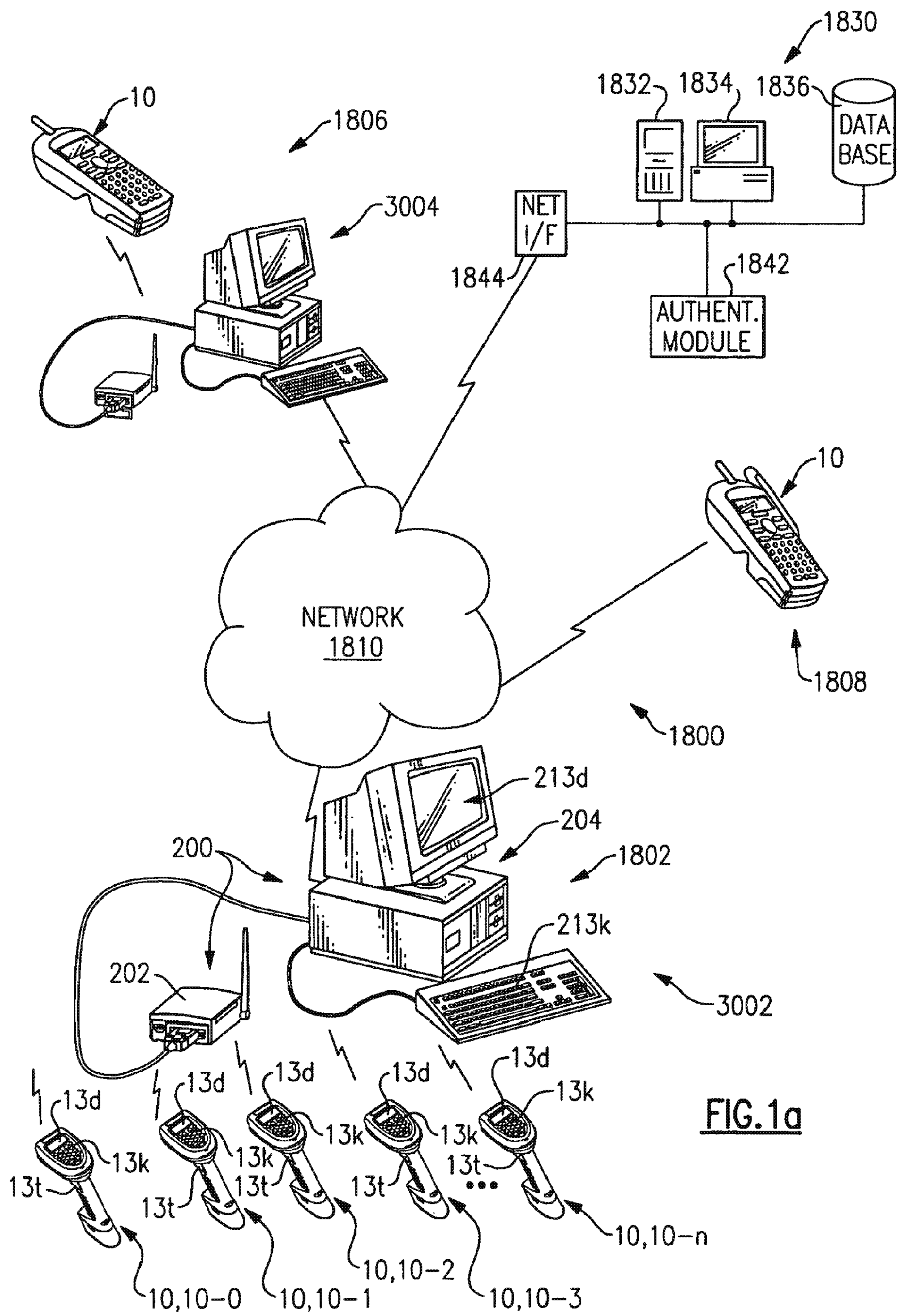

1830
1832
1834
1836
DATA BASE
10
1806
3004
NET I/F
1844
1842
AUTHENT. MODULE
10
NETWORK 1810
1808
1800
213d
204
1802
200
213k
202
3002
13d
13k
13t
10,10-0
10,10-1
10,10-2
10,10-3
10,10-n

FIG.1a

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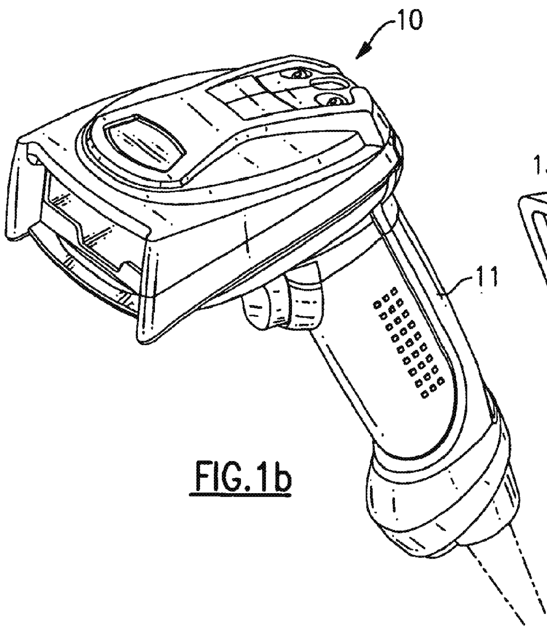


FIG.1b

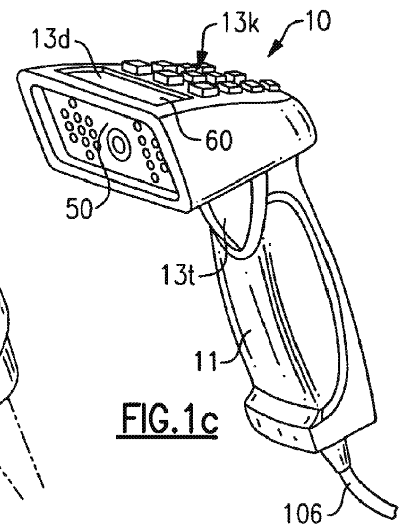


FIG.1c

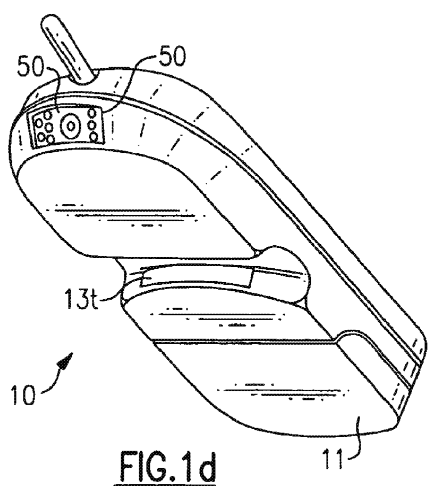


FIG.1d

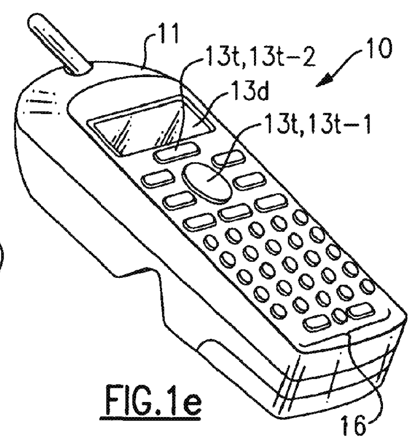


FIG.1e

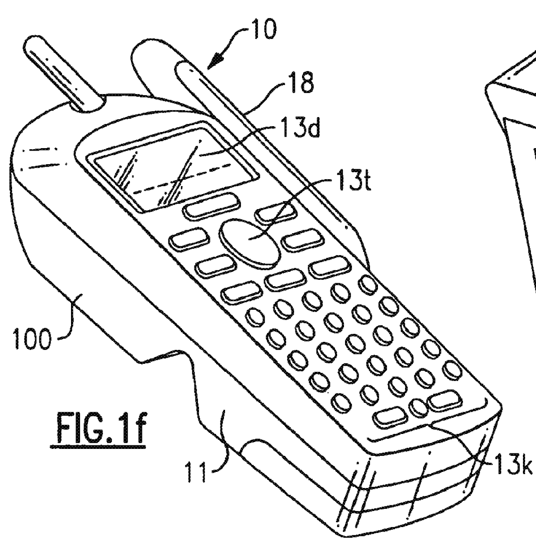


FIG.1f

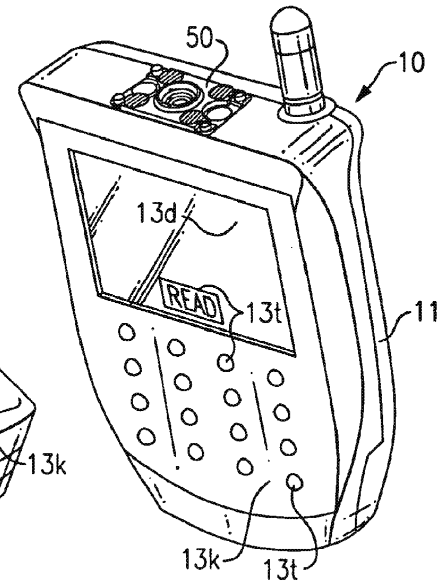
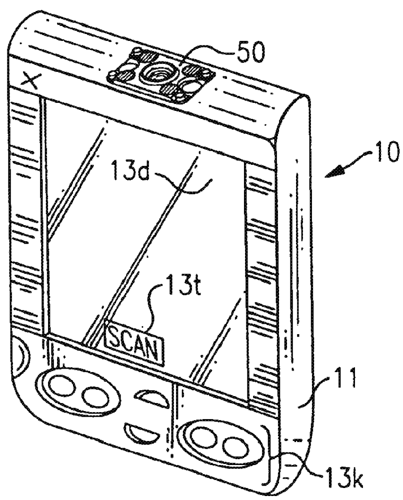


FIG.1g

FIG.1h



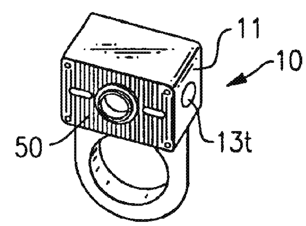


FIG.1i

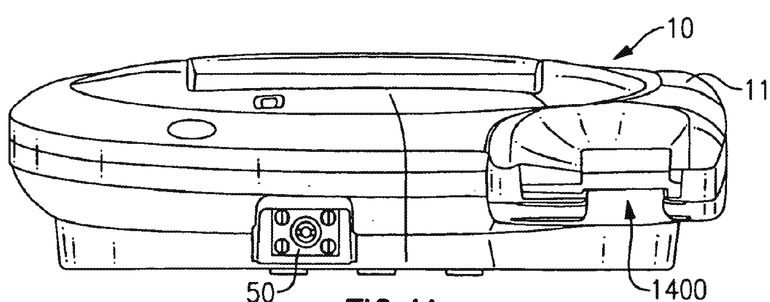


FIG.1j

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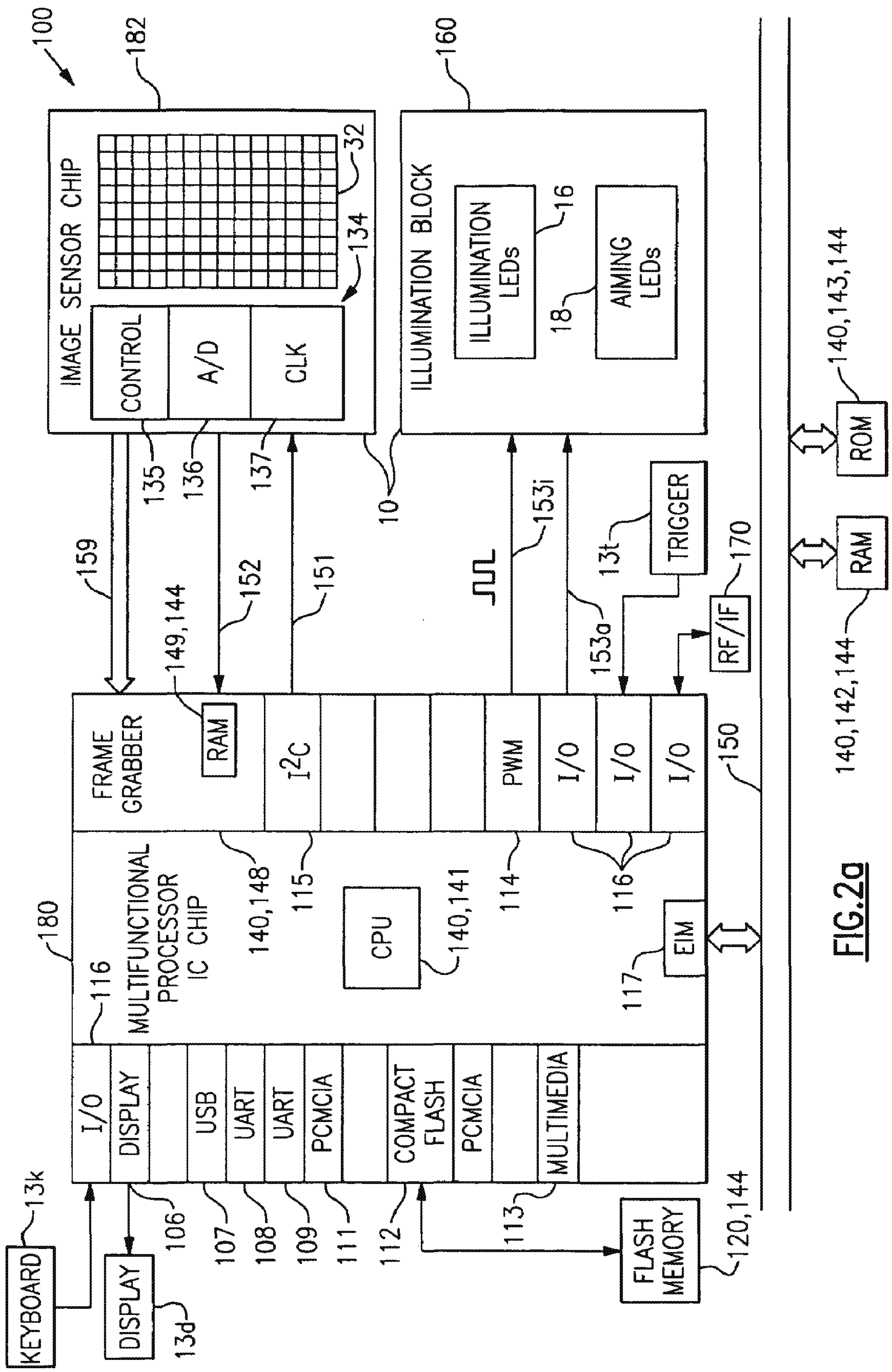

FIG.2a

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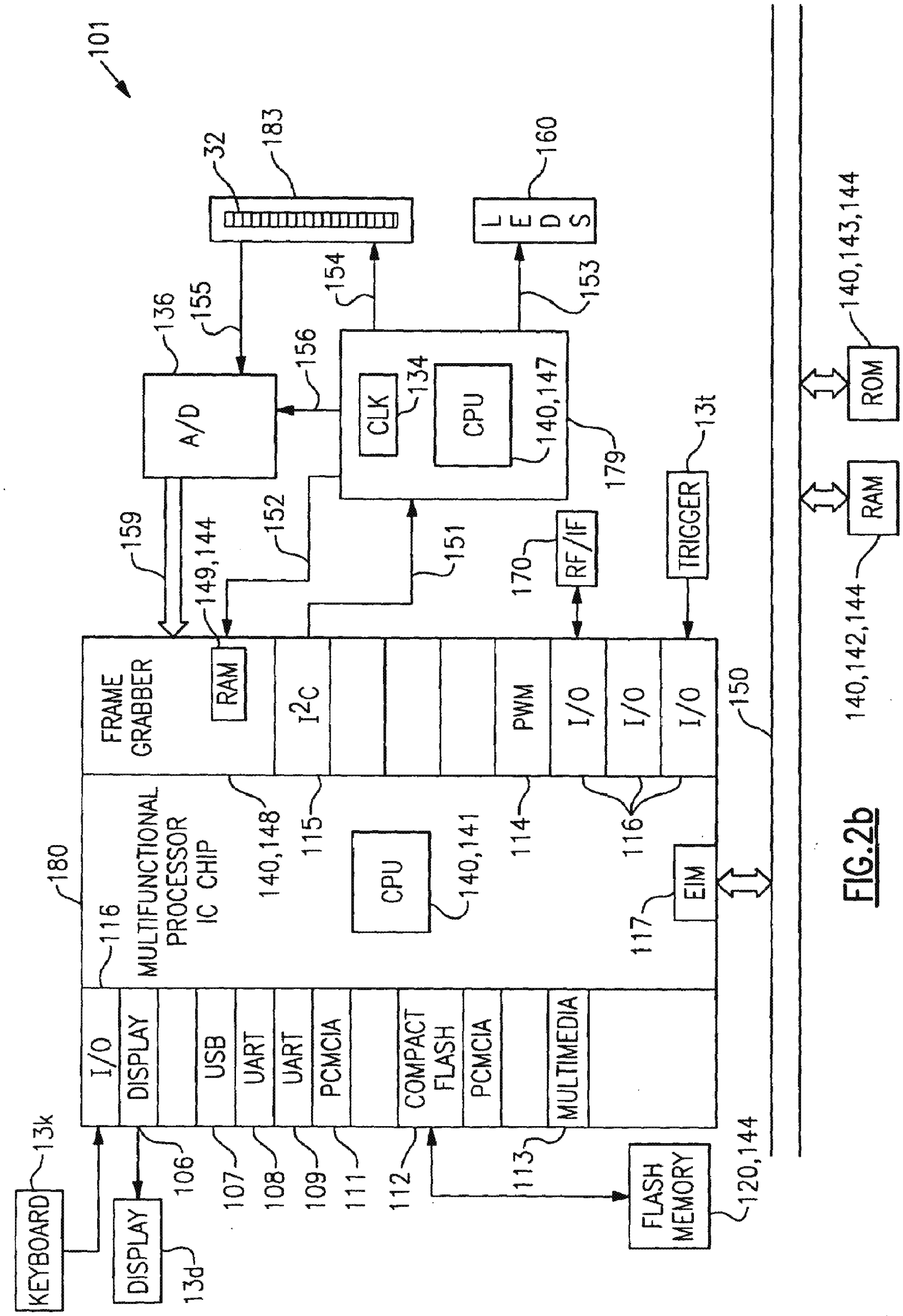
101
32
183
160
L E D S
136
155
154
153
140,143,144
A/D
156
CLK
134
CPU
140,147
179
ROM
RAM
13t
TRIGGER
159
149,144
152
151
170
RF/IF
140,142,144
FRAME GRABBER
RAM
I2C
PWM
I/O
I/O
I/O
150
180
116
MULTIFUNCTIONAL PROCESSOR IC CHIP
140,148
115
CPU
140,141
114
116
117
EIM
I/O
DISPLAY
USB
UART
UART
PCMCIA
COMPACT FLASH
PCMCIA
MULTIMEDIA
13k
KEYBOARD
DISPLAY
13d
106
107
108
109
111
112
113
FLASH MEMORY
120,144

FIG.2b

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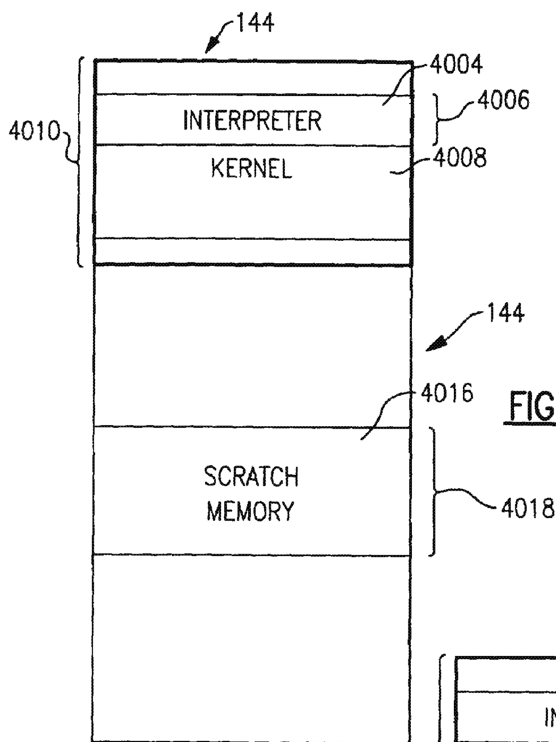

FIG.3a

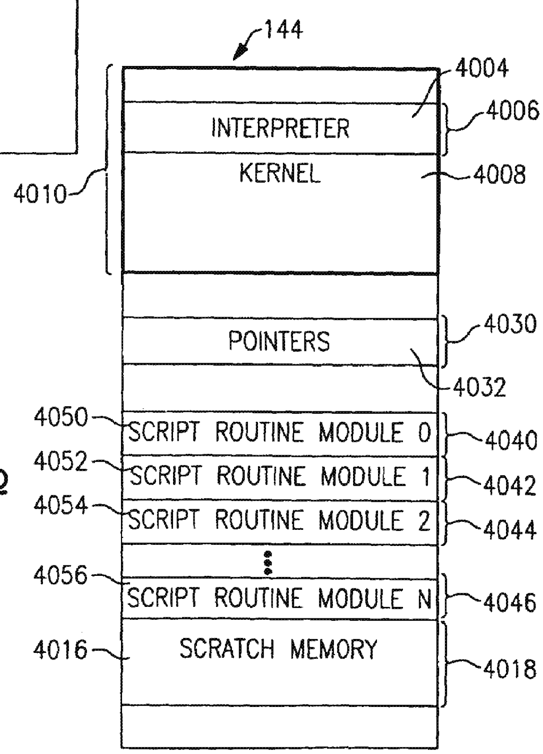

FIG.3b

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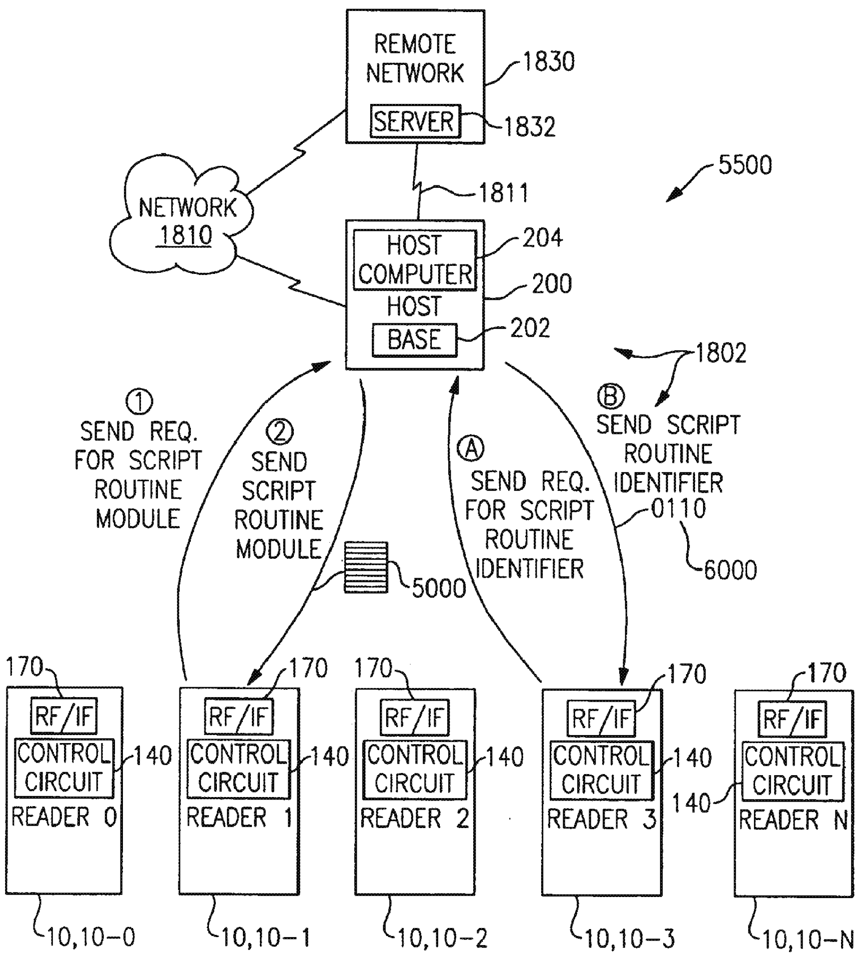
REMOTE NETWORK
SERVER
1830
1832
NETWORK 1810
1811
5500
HOST COMPUTER
HOST BASE
204
200
202
1802
① SEND REQ. FOR SCRIPT ROUTINE MODULE
② SEND SCRIPT ROUTINE MODULE
Ⓐ SEND REQ. FOR SCRIPT ROUTINE IDENTIFIER
Ⓑ SEND SCRIPT ROUTINE IDENTIFIER
0110
6000
5000
170
RF/IF
CONTROL CIRCUIT
140
READER 0
READER 1
READER 2
READER 3
READER N
10,10-0
10,10-1
10,10-2
10,10-3
10,10-N

FIG.4a

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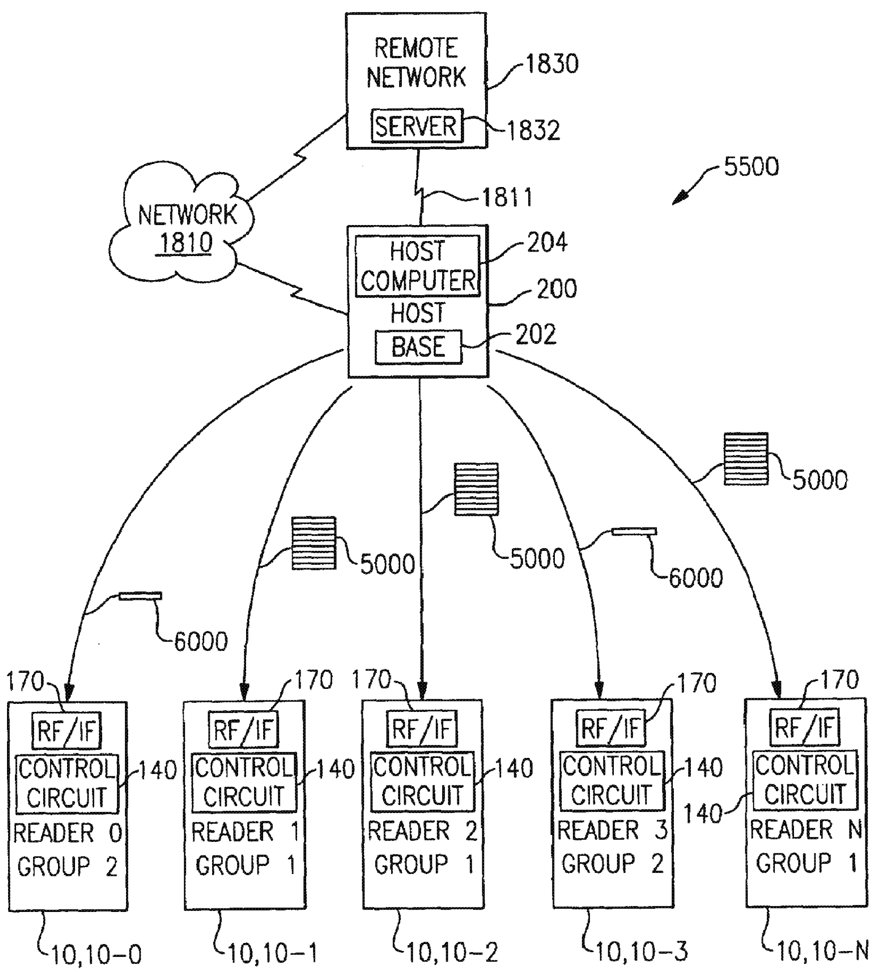
REMOTE NETWORK
1830
SERVER
1832
5500
1811
NETWORK 1810
HOST COMPUTER
204
200
HOST BASE
202
5000
5000
5000
6000
6000
170
RF/IF
CONTROL CIRCUIT
140
READER 0 GROUP 2
READER 1 GROUP 1
READER 2 GROUP 1
READER 3 GROUP 2
READER N GROUP 1
10,10-0
10,10-1
10,10-2
10,10-3
10,10-N

FIG.4b

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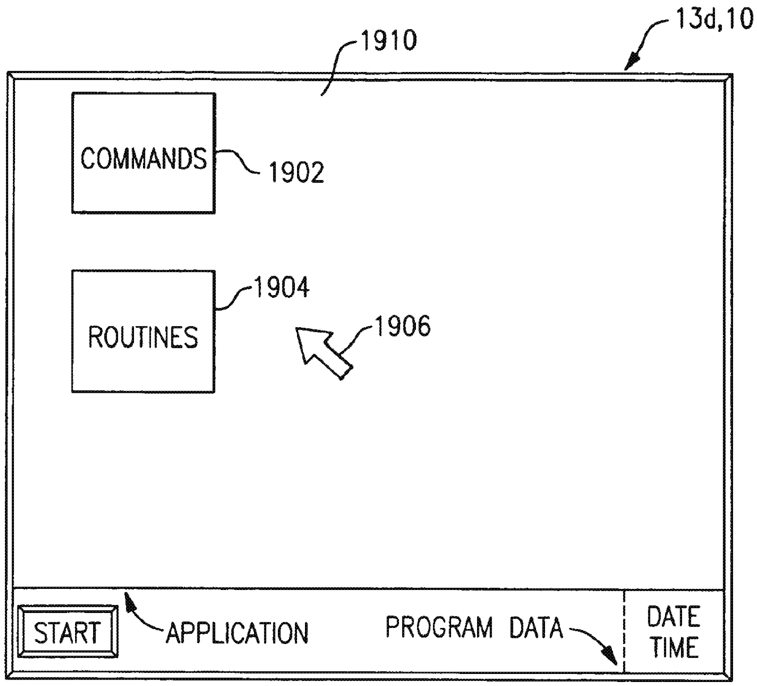

FIG.5a

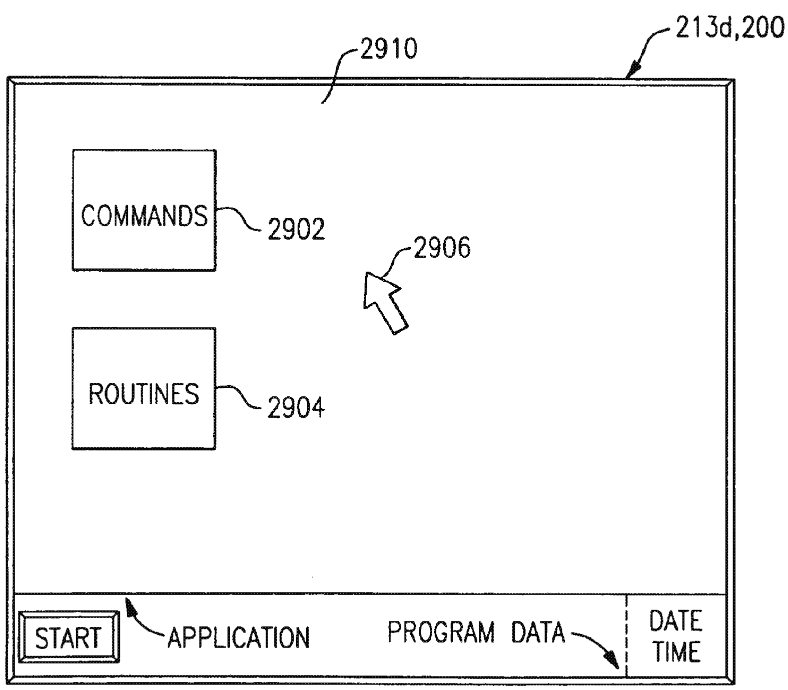

FIG.5b

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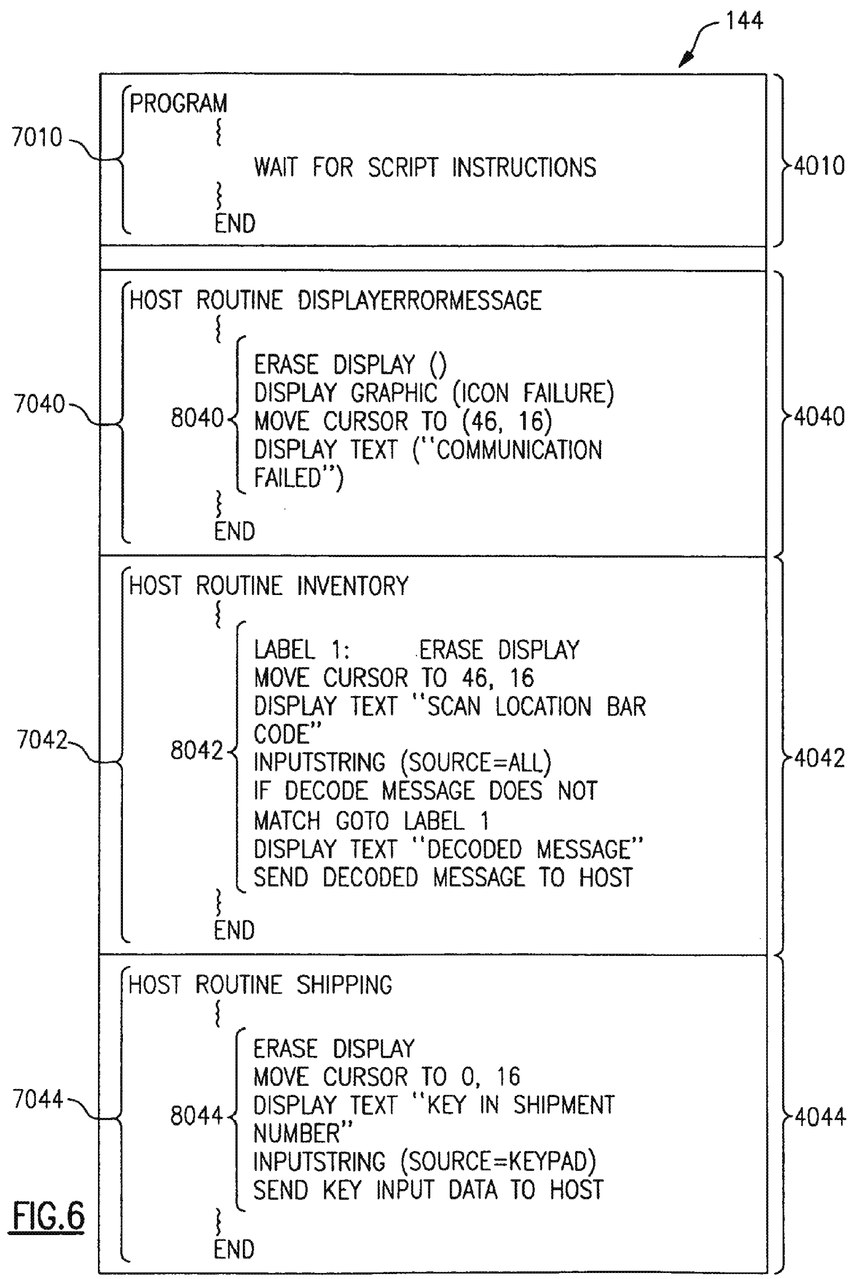

FIG.6

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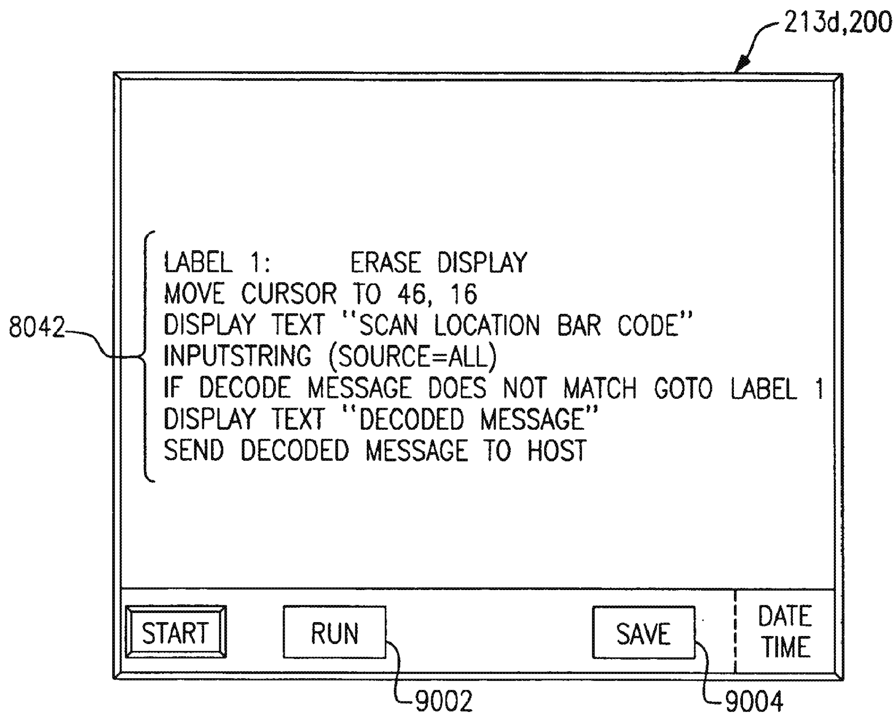
213d,200
8042
LABEL 1: ERASE DISPLAY
MOVE CURSOR TO 46, 16
DISPLAY TEXT ''SCAN LOCATION BAR CODE''
INPUTSTRING (SOURCE=ALL)
IF DECODE MESSAGE DOES NOT MATCH GOTO LABEL 1
DISPLAY TEXT ''DECODED MESSAGE''
SEND DECODED MESSAGE TO HOST
START
RUN
SAVE
DATE
TIME
9002
9004

FIG.7

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CUSTOMIZABLE OPTICAL READER

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 10/402,885, filed Mar. 28, 2003 now U.S. Pat. No. 6,959,856, entitled "Customizable Optical Reader" which claims the priority of provisional U.S. Application No. 60/368,375, filed Mar. 28, 2002, entitled, "Customizable Optical Reader Having Multiple User Selectable Instruction Execution Protocols." Priority to both of the above applications is claimed and both of the above applications are herein incorporated by reference in their entirety.

FIELD OF THE INVENTION

This invention relates generally to optical readers and specifically to system and methods for reprogramming optical readers.

BACKGROUND OF THE INVENTION

Optical readers tend to fall into one of three categories: wand readers, laser scan engine optical readers and image sensor based optical readers.

Wand readers generally comprise a single light source and single photodetector housed in a pen shaped housing. A user drags the wand reader across a decodable symbol (e.g., a bar code) and a signal is generated representative of the bar space pattern of the bar code.

Laser scan engine based optical readers comprise a laser diode assembly generating a laser light beam, a moving mirror for sweeping the laser light beam across a decodable symbol and a signal is generated corresponding to the decodable symbol.

Image sensor based optical readers comprise multi element image sensors such as CID, CMOS, or CCD image sensors and an imaging optic for focusing an image onto the image sensor. In operation of an image sensor based optical reader, an image of a decodable symbol is focused on an image sensor and a signal is generated corresponding to the signal. Image sensor elements may be arrayed in a line or in a rectangular matrix or area. Area image sensors capture a digital picture and use software algorithms to find and decode one or more symbols.

Users of laser scanner engine based optical readers have been switching in increasing numbers to image sensor based optical readers. Image sensor based optical readers are more durable and offer additional features relative to laser scan engine based bar code readers. Features and functions which have been incorporated into image sensor based optical readers involve image processing.

An image sensor based optical reader having image processing functionality is described in U.S. Pat. No. 6,298,176, issued Oct. 2, 2001, entitled "Symbol-Controlled Image Data Reading System," assigned to the assignee of the present invention and incorporated by reference. In the patent, an optical reader is described which reads an image data reading instruction symbol and which outputs image data which may include signature data in manner that depends on the information encoded in the image reading instruction symbol.

The added functionality possible with optical readers, coupled with reduced costs, have made optical readers attractive to an ever-widening market of users who seek to employ optical readers in an ever-growing variety of applications. Manufacturers of optical readers have been tested in satisfying all of their customer demands for readers, which can satisfy a greater variety of optical reader applications. Accordingly, there is a need for an optical reader which can readily be custom programmed to operate in a manner consistent with a user's particular application.

SUMMARY OF THE INVENTION

According to its major aspects and broadly stated in the invention is a customizable optical reader, which may be programmed in a variety of ways.

In one aspect, the invention includes an optical reader including script interpreter enabling the reader to execute complex and varied commands and strings of commands (which may be referred to as "script routine modules") during execution of a main program.

In another aspect, the invention includes an optical reader, which is operable in a "host commands" mode and a "host routines" mode. In the "host commands" mode, the reader receives and executes a script routine module from a host. In the "host routines" mode the reader receives a script routine module identifier from the host, and the reader, in turn, executes a selected one of a plurality of reader-stored script routine modules based on the identifier.

These and other details, advantages and benefits of the present invention will become apparent from the detailed description of the preferred embodiment and the associated drawings.

BRIEF DESCRIPTION OF THE DRAWING

For a further understanding of these and objects of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawing, wherein:

FIG. **1***a* is a schematic/physical view of an optical reader network;

FIGS. **1***b*–**1***j* are prospective views of various readers according to the invention;

FIGS. **2***a*–**2***b* are electrical block diagrams of readers according to the invention;

FIGS. **3***a*–**3***b* are memory maps illustrating an implementation of the invention;

FIG. **4***a* is a schematic/flow diagram illustrating an implementation of the invention;

FIG. **4***b* is a schematic/flow diagram illustrating another implementation of the invention;

FIGS. **5***a* and **5***b* illustrate user interfaces which may be utilized in an implementation of the invention;

FIG. **6** is a memory map illustrating further aspects of the invention;

FIG. **7** is an exemplary user interface illustrating further aspects of the invention.

DETAILED DESCRIPTION OF THE INVENTION

An optical reader network **1800** is shown in physical form/schematic view of FIG. **1***a*. Network **1802** at multiple reader work location **3002** may be a local area network (LAN) including a plurality of optical readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N. Each of the readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N is in radio communication with base **202** of host **200**, which, along with host computer **204** make up host **200**. Host **200**, in turn, is in communication with network **1810**. Network **180** may be part of the Internet. However, network

1810 may also be a private network. Through network **1810** host **200** is in communication with customer service center network **1830** which is typically maintained by the supplier and/or manufacturer of readers **10**. Customer service network **1830** may include (e.g., network interface device **1844**, a server **1832**, several personal computers of which computer **1834** is representative, a database **1836** and an authentication module **1842**) which allows only registered users to access the contents of database **1836**. Resident on server **1832** of customer service network **1830** is an internet website allowing users of reader **10** to access information about reader **10** including reader loadable programs and/or program instructions which may be loadable on to readers **10**. Network **1830** may be a local area network (LAN) but often is provided by a wide-area network (WAN) having components spread out over various locations.

Also in communication with network **1810** (and with customer service network **1830** through network **1810**) are readers at work locations other than work location **1804**. At location **1806**, a single reader **10** having a network interface incorporated therein is in communication with network **1810**. At location **3004**, a network **1806** is provided including a single reader **10** in communication with a host **400** in communication with network **1810**. Each communication link of network **1800** may be wired or in the alternative, wireless.

From time to time it is useful to reprogram readers **10-0**, **10-1** **10-2**, **10-3**, **10**-N. For example, if a manufacturer/supplier develops a new software function which may be executed by readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N, it would be beneficial to load that software into readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N. At location **3002**, an application for readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N may change. Readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N may be required to operate to satisfy required functions of a first application and then, a second application. Readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N or a subset of readers **10-0**, **10-1**, **10-2**, **10-2**, **10-3**, **10**-N may be required to satisfy required functions of e.g., a generic (i.e., any customer) inventory application, a generic shipping application, a generic receiving application, a generic point of sale application, a customer-specific shipping application, a customer-specific receiving application or a customer-specific point of sale application. For example, a customer may use readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N 364 days a year in a point of sale operation, and one day a year in an inventory application.

An individual reader (e.g., reader **10-0**) operates at its fastest speed if it does not have to communicate with any other device such as host **200** during execution of a main operating program resident thereon. Thus, a reader (e.g., reader **10-0**) would operate at its fastest possible speed if an operating program, such as a compiled program with no script interpreter, were loaded thereon having all the program routines that were necessary for the operation of the reader in a particular application. However, the installation of a new operating program is often a painstaking, time-consuming process. The individual reader **10** has to be linked to a host **200**, and an entire operating program has to be downloaded into reader **10**, a process that can take at least several seconds, and up to several minutes, and is subject to failure. The reprogramming of each or several readers can be a logistical challenge given that readers are typically distributed at various locations throughout a work location, especially considering that a work location in accordance with the invention can comprise a wide geographic area (e.g., an entire continent or country). If the number of readers, N, is large, it can be seen that full-operating

program reprogramming would result in extremely long delays and would perhaps not be worth the effort if a special programming function were needed only for a short duration of time, or for one isolated particular application.

Housings **11** for optical readers in which the invention can be employed are shown in FIGS. **1***b*–**1***j*. In FIG. **1***b*, a gun style optical reader is shown as described in copending application Ser. No. 10/339,275, filed Jan. 9, 2003, entitled "Housing For Optical Reader," incorporated by reference. An imaging module (not shown) is incorporated in the reader housing **11**. In FIG. **1***c*, a gun style reader **10** is shown having an integrated keyboard **13***k* and display **13***d*. In FIGS. **1***d*–**1***e*, a portable data terminal (PDT) style reader is shown having a keyboard **13***k* and a display **13***d*. In FIG. **1***g*, an embodiment is shown wherein display **13***d* includes an associated touch screen overlay and which further includes a stylus **18** for entering signature information. In FIG. **1***g*, a cellular phone reader **10** is shown which has a display **13***d* and keyboard **13***k* and which incorporates an imaging module **50** as is described in U.S. patent application Ser. No. 10/092,789, filed Mar. 7, 2002, entitled, "Optical Reader Imaging Module," incorporated by reference. In the embodiment of FIG. **1***h*, a reader comprises a portable data assistant (PDA). In the embodiment of FIG. **1***e*, reader **10** includes housing **11** configured to be worn on a user's finger. In FIG. **1***j*, reader **10** is in the form factor of a transaction terminal, and includes a card reader **1400**, as is more fully described in U.S. patent application Ser. No. 10/339,444, filed Jan. 9, 2003, entitled "Transaction Terminal Comprising Imaging Module." Numerous other form factors are possible. For example, in the previously incorporated U.S. patent application Ser. No. 10/092,789, filed Mar. 7, 2002, entitled, "Optical Reader Imaging Module," incorporated by reference, a pen style optical reader is shown. In U.S. patent application Ser. No. 09/432,282, filed on Nov. 2, 1999, entitled, "Indicia Sensor System For Optical Reader," incorporated by reference, a reader is shown which rests on a "scan stand."

For a better understanding of the invention, exemplary electrical hardware features of optical readers **10** are described with reference to FIGS. **2***a* and **2***b*.

In FIG. **2***a*, a block diagram of an optical reader electrical circuit is shown having a multi-functional processor IC chip **180** including an integrated frame grabber block **148**. Electrical circuit **100** shown in FIG. **2***a* can be utilized for control of a single 2D imaging module optical reader as is shown for example in U.S. Ser. No. 09/954,081 filed Sep. 17, 2001, entitled "Optical Reader Having Image Parsing Mode," which is hereby incorporated herein by reference in its entirety.

In the specific embodiment of FIG. **2***a*, electrical circuit **100** includes a control circuit **140** comprising CPU **141**, system RAM **142** and system ROM **143** and frame grabber block **148**. Electrical circuit **100** further includes an image sensor **32** typically provided by a photosensitive array and an illumination block **160** having illumination LEDs **16** and aiming LEDs **18** as shown in the physical form view of FIGS. **3***a*–**3***c*. Image sensor **32** of FIG. **2***a* is shown as being provided by a 2D photo diode array. If a 1D image sensor replaces image sensor **32**, then aiming LEDs **18** and illumination LEDs **16** may be constituted by one set of LEDs. In the embodiment shown, image sensor **32** incorporated in an image sensor IC chip **182** which typically further includes an image sensor electrical circuit block **134**. Image sensor electrical block **134** includes control circuit **135** for controlling image sensor **32**, an A/D conversion circuit **136**, for

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converting analog signals received from image sensor **32** into digital form and integrated clock **137** sometimes referred to as an oscillator.

In the embodiment shown in FIG. **2***a*, CPU **141** and frame grabber block **148** are incorporated in a multi-functional IC chip **180**, which in addition to including CPU **141** includes numerous other integrated hardware components. Namely, multi-functional IC chip **180** may include a display control block **106**, several general purpose I/O ports **116**, several interface blocks such as a USB circuit block **107** and a UART block **108** for facilitating RS **232** communications, a UART block **109** for facilitating infrared communications (including communication according to standards promulgated by the INFRARED DATA ASSOCIATION® (IrDA®), a trade association for defining infrared standards), and a pulse width modulation (PWM) output block **110**. Multi-functional processor IC chip **180** can also have other interfaces such as a PCMCIA interface **111**, a compact flash interface **112**, and a multimedia interface **113**. Electrical circuit **100** could also include an RF interface **170** in communication with I/O interface **116** providing communication with an external device such as host **200**. If reader **5** includes a display **13***d*, display **13***d* may be in communication with chip **180** via display interface **106**. Trigger **13***t* and keypad **13***k* may be in communication with chip **180** via general purpose I/O interface **116**. Physical form views of readers having displays and keyboards are shown, for example, in U.S. application Ser. No. 10/137,484, filed May 2, 2002, entitled "Optical Reader Comprising Keyboard," which is hereby incorporated herein by reference in its entirety. Multi-functional processor IC chip **180** may be one of an available type of multifunctional IC processor chips which are presently available such as a Dragonball MX1 IC processor chip or a Dragonball MXL IC processor chip available from Motorola, a DSC IC chip of the type available from Texas Instruments, an O-Map IC chip of the type available from Texas Instruments, or a multifunctional IC processor chip of a variety known as Clarity SOCs (e.g., system on a chip) available from Sound Vision, Inc.

In one embodiment, multi-functional processor IC chip **180** comprises components that provide at least the functions provided by a CPU **140**, system RAM **142** and system ROM **143**. In some embodiments, it is advantageous that microprocessor-based decoder module **180** comprises an integrated circuit device having integrated therein a microprocessor, an analog-to-digital converter, a digital-to-analog converter, a direct memory access (DMA) channel, a bi-directional communication line for communication with a sensor such as either or both of line **151** and **152**, and a channel for data receipt from a sensor, such as data line **159** that brings data to frame grabber **148**. The microprocessor-based IC chip **180** can comprise semiconductor materials, optical materials, and photonic bandgap materials. In some embodiments, it is advantageous that the multi-functional processor IC Chip **180** further comprise I/O **116** suitable to accept user input (for example, from a keyboard **13***k*), interface capability for "flash" memory devices such as "Multimedia" (MMC), "Smart Media," "Compact Flash," and "Memory Stick." Other features that may be used to advantage include pulse width modulators (PWMs), serial communication channels (e.g., UARTs, SPIs, and USBs), display drivers and controllers such as for an LCD, wireless communication capability such as Bluetooth and 802.11(a), (b), and (g)-compatible transmitter/receivers, sequence control modules such as timer banks, sensor controllers, audio generators, audio coder/decoders ("codecs"), speech synthesizers, and speech recognition hardware and/or software.

Frame grabber block **148** of IC chip **180** replaces the function of a frame grabbing field programmable gate array (FPGA) as discussed in commonly assigned U.S. patent application Ser. No. 09/954,081, filed Sep. 17, 2001, entitled, "Imaging Device Having Indicia-Controlled Image Parsing Mode," and U.S. patent application Ser. No. 09/904,697, filed Jul. 13, 2001, entitled "An Optical Reader Having a Color Imager," both of which are hereby incorporated herein by reference in their entirety. More particularly, frame grabber block **148** is specifically adapted collection of hardware elements programmed to carry out, at video rates or higher, the process of receiving digitized image data from image sensor chip **182** and writing digitized image data to system RAM **142** which in the embodiment shown is provided on a discreet IC chip. Frame grabber block **148** includes hardware elements preconfigured to facilitate image frame capture. Frame grabber block **148** can be programmed by a user to capture images according to a user's system design requirements. Programming options for programming frame grabber block **148** include options enabling block **148** to be customized to facilitate frame capture that varies in accordance with image sensor characteristics such as image sensor resolution, clockout rating, and fabrication technology (e.g., CCD, CMOS, CID), dimension (1D or 2D), tonality (from 1 to N-bits), color (monochrome or color), biometric features, such as fingerprints, retinal patterns, facial features, and one-and two-dimensional patterns that can provide information, such as chromatography patterns and electrophoretic patterns of mixtures of substances, including substances such as biological samples comprising DNA. A decoder board that automatically adapts itself to satisfy the image capture requirements of a presently attached image sensor is described in U.S. patent application Ser. No. 10/339,439, filed Jan. 9, 2003, entitled, "Decoder Board For An Optical Reader Utilizing A Plurality Of Imaging Formats," incorporated by reference. Aspects of the operation of circuit **100** when circuit **100** captures image data into RAM **140** are now described. Circuit **100** can perform a cycle of receiving a frame of image data, performing internal programming functions, and decoding the frame of image data in a time period of less than or equal to a second. In a more preferred embodiment, the circuit **100** performs the cycle in a time period of less than or equal to 1/30 of a second. It is expected that in a still more preferred embodiment, the time period can be less than or equal to 1/270 of a second. When trigger **13***t* is pulled, CPU **141**, under the operation of a program stored in system ROM **143**, writes an image capture enable signal to image sensor chip **182** via communication line **151**. Line **151**, like the remainder of communication lines described herein represents one or more physical communication lines. In the embodiment shown, wherein image sensor chip **182** is of a type available from IC Media Corp., I^2C interface **115** of chip **180** is utilized to facilitate communication with chip **182** (if another image sensor chip is selected another type of interface e.g. interface **116** may be utilized). Other types of signals may be sent over line **151** during the course of image capture. Line **151** may carry, for example, timing initialization, gain setting and exposure setting signals.

When control block **135** of image sensor chip **182** receives an image capture enable instruction, control block **135** sends various signals to frame grabber block **148**. Image sensor control block **135** typically sends various types of synchronization signals to frame grabber block **148** during the course of capturing frames of image data. In particular, control block **135** may send to frame grabber block **148**

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"start of frame signals" which inform frame grabber block **148** that chip **182** is ready to transmit a new frame of image data, "data valid window" signals which indicate periods in which a row of image data is valid, and "data acquisition clock" signals as established by clock **137** controlling the timing of image data capture operations. In the embodiment described, line **152** represents three physical communication lines, each carrying one of the above types of signals. In an alternative embodiment, vertical and horizontal synchronization signals are processed by frame grabber **148** to internally generate a data valid window signal. Frame grabber block **148** appropriately responds to the respective synchronization signals, by establishing buffer memory locations within integrated RAM **149** of block **148** for temporary storage of the image data received from image sensor chip **182** over data line **159**. At any time during the capture of a frame of image data into system RAM **142**, buffer RAM **149** of frame grabber block **148** may store a partial (e.g., about 0.1 to 0.8) or a full line of image data.

Referring to further aspects of electrical circuit **100**, circuit **100** includes a system bus **150**. Bus **150** may be in communication with CPU **141** via a memory interface such as EIM interface **117** of IC chip **180**. System RAM **142** and system ROM **143** are also connected to bus **150** and in communication with CPU **141** via bus **150**. In the embodiment shown, RAM **142** and ROM **143** are provided by discreet IC chips. System RAM **142** and system ROM **143** could also be incorporated into processor chip **180**.

In addition to having system RAM **142**, sometimes referred to as "working" RAM, electrical circuit **100** may include one or more long-term storage devices. Electrical circuit **100** can include for example an "flash" memory device **120**. Several standardized formats are available for such flash memory devices including: "Multimedia" (MMC), "Smart Media," "Compact Flash," and "Memory Stick." Flash memory devices are conveniently available in card structures which can be interfaced to CPU **141** via an appropriate "slot" electromechanical interface in communication with IC chip **180**. Flash memory devices are particularly useful when reader **5** must archive numerous frames of image data. Electrical circuit **100** can also include other types of long term storage such as a hard drive which may be interfaced to bus **150** or to an appropriate I/O interface of processor IC chip **180**.

In a further aspect of electrical circuit **100**, control circuit **140** is configured to control the turning off and turning on of LEDs **16**, **18** of illumination block **160**. Control circuit **140** preferably controls illumination block **160** in a manner that is coordinated with the capturing of the frames of image data. Illumination LEDs **16** are typically on during at least a portion of frame capture periods. Configuring circuit **140** so that LEDs **16**, **18** have off periods significantly reduces the power consumption of circuit **100**.

In a further aspect of the electrical circuit **100**, electrical circuit **100** can be configured so that PWM output interface **114** of IC chip **180** controls illumination LEDs of an imaging module such as illumination LEDs **16** of module **10-1** or aiming/illumination LEDs **18** of module **10-2**.

In one embodiment, illumination block **160** is in communication with PWM output interface **114** and configured in such manner that LEDs **16** are turned on at a leading edge of PWM pulses output at PWM interface **114**, and are turned off at falling edges of PWM pulses output at PWM interface **114**. PWM interface **114** should be configured so that several pulses are generated and sent over communication line **153*i*** during the time that a single row of pixels of image data are exposed to light prior to clocking out of pixel values corresponding to that row. Thus, illumination LEDs **16** would be turned on and off several times during the exposure period for exposing a row of pixels to light. Further, the number of pulses output by PWM output **114** during the time that a single row of pixels are exposed should not vary substantially from row to row. The pixel clock signal received at frame grabber block **148** of IC chip **180** can be utilized to generate the PWM output. It can be seen, therefore, that multifunctional IC chip **180** including frame grabber block **148** and PWM output **114** greatly simplifies the task of developing PWM signals for use in controlling illumination LEDs **16** of module **10**.

In another embodiment, PWM output **114** and illumination block **160** are configured so that PWM output **114** controls the intensity of illumination, not the on time/off time of illumination. Illumination LED block **160** in such an embodiment can include a power supply circuit which is interfaced to PWM output **114** such that the PWM signal output at PWM output **114** varies the voltage or current supplied to LEDs **16**.

In a further aspect of electrical circuit **100**, aiming LEDs **18** of circuit **100** can be controlled by a signal transmitted by a general purpose I/O port **116** of IC chip **180** over communication line **153*a***. Multifunctional processor IC chip **180** can be programmed so that an aiming LED control signal is caused to change to an "ON" state when frame grabber block **148** completes the process of capturing a complete frame of image data. Frame grabber block **148** may be configured to generate an "end of acquisition" or "end of frame" signal when frame grabber block **148** completes the process of capturing a complete frame of image data into RAM **142**. When CPU **141** receives an "end of acquisition" signal, CPU **141** controls I/O port **116** to change the state of an LED control signal. Control circuit **140** may also change the state of an LED control signal when generating a start of frame signal. Control circuit **140** may execute a delay prior to changing the state of an LED signal. Control circuit **140** is programmed so that an LED control signal remains in an "ON" state known to be sufficiently short duration so as not to cause actuation of an aiming LED **18** during a succeeding frame exposure period. Configured in the manner described, aiming LEDs **18** are selectively pulsed on for a short duration during intermediate successive frame exposure periods, e.g. frame exposure periods.

Referring now to FIG. 2*b*, electrical circuit **101** is described. Electrical circuit **101** controls operation of a single imaging module optical reader comprising a low cost 1D CCD image sensor **32** incorporated on IC chip **183**. Image sensor **32** of FIG. 2*b* may be provided for example by a Toshiba Model TCD 1304 AP linear image sensor. Further aspects of an exemplary ID imaging module are described, for example, in application Ser. No. 09/658,811, filed Sep. 11, 2000, entitled "Optical Assembly for Barcode Scanner," which is hereby incorporated herein by reference in its entirety.

Referring to aspects of electrical circuit **101** in detail, electrical circuit **101** includes a control circuit **140** which, like control circuit **140** of circuit **100** is partially incorporated in a multifunctional processor IC chip **180** including CPU **141** and a frame grabber block **148**. Control circuit **140** of circuit **101** further includes system RAM **142** system ROM **143** and supplementary central processor unit (CPU) **147**, integrated on processor IC chip **179**. System RAM **142** and system RAM **143** are in communication with EIM interface **117** of IC chip **180** via bus **150**.

Processor IC chip **179** provides control and timing operations similar to that provided by electrical block **134** of

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image sensor chip **182** described in FIG. **1***a*. Processor IC chip **179**, in general, sends synchronization signals and digital clocking signals to IC chip **180**, and sends digital clocking signals to A/D conversion circuit **136** and image sensor **32**. Processor IC chip **179** of circuit **101** may be a relatively low power processor IC chip such as an 8-bit Cypress Programmable System-on-Chip™ (PSOC™) CY8C26Z33-24PZI Microcontroller processor IC chip available from Cypress MicroSystems of Bothell, Wash. Aspects of the operation of IC chip **179** in during the course of capturing slice image data will now be described in detail. When trigger **13***t* is pulled, CPU **141** transmits enable image capture instructions over communication line **151**. However, a user defined script instruction or module (a set of script instructions) when executed by reader **10**, may override such a normal functioning of trigger **13***t* as a capture enable actuation. In response to receipt of an image capture enable instructions received from chip **180**, processor IC chip **179** performs a variety of operations. Processor IC chip **179** may send synchronization signals, such as "start of scan," "data valid window," and "data acquisition clock" signals to frame grabber block **148** via communication line **152**. Processor IC chip **179** may also send timing signals and digital clocking signals (e.g. master clock, integration clear gate, and shift gate pulse) to image sensor **32**. Processor IC chip **179** typically also transmits a master clock signal to A/D conversion circuit **136**. Referring to further aspects of IC chip **180** of circuit **101**, CPU **141** of chip **180**, may also send e.g. gain setting, exposure setting, and timing initialization signals via line **151** to IC chip **179**. Communication between IC chip **180** and IC chip **179** may be made via an SPI interface or I/O interface **116** of chip **180** and chip **179**.

As will be explained with reference to circuit **104**, shown in FIG. **2***e*, processor IC chip **179** may be replaced by a programmable logic circuit, e.g. a PLD, CPLD, or an FPGA. IC chip **179** could also be replaced by an ASIC. Electrical circuit **101** of FIG. **2***b*, includes what may be termed a "digital digitizer" in that analog voltage levels transmitted by CCD image sensor **32** on line **155** are converted into gray scale pixel values by A/D converter **136** and transmitted via line **159** to frame grabber block **148**. Circuit **101** could also include an analog digitizer which processes an analog signal generated by image sensor **32** to generate a two-state output signal that changes state in accordance with light-to-dark and dark-to-light transitions of the image sensor analog output signal.

Processor IC chip **179** also controls LED bank **160**. LED bank **160** of a 1D image sensor reader typically includes a single bank of LEDs, which simultaneously illuminates a target area and provides an aiming pattern facilitating aligning of the reader with a target indicia.

Reader memory **144** of circuit **100** and of circuit **101** in the specific embodiments of FIGS. **2***a* and **2***b* includes system RAM **144**, program ROM **143**, on-board RAM **149**, and flash memory **120**.

In embodiments described, reader **10** includes an imaging assembly including an image sensor having a plurality of photosensors and an aiming/illumination system having LEDs **16**, **18**. In the alternative, an imaging assembly of reader **10** could be wand style (e.g., including a single photodetector and light source assembly which is manually moved across a target) or laser scan image engine based (e.g., including (a) a laser diode assembly generating a laser beam which is automatically swept across a target, and (b) a single photodetector). Referring now to particular aspects of the invention, a reader, according to the invention, includes a script/interpreter programming architecture. In a script/interpreter programming architecture, as is explained with reference to the memory map diagram of FIG. **3***a*, an interpreter **4004** is resident in address locations **4006** of memory **144** as part of a main operating program or "kernel". As will be explained in more detail herein, reader **10** may be programmed to wait for a script instruction or script routine module to be received from host **200**. When the script instruction routine module is received from host **200**, interpreter **4004** interprets the module and control circuit **140** executes the module. Control circuit **140** executes instruction of the script routine module without compiling the instruction of the script routine module together with the remaining instructions that make up of kernel **4008**. During execution of the instructions that make up a script execution section, control circuit **144** executes a script routine module, a set of instructions that are not part of kernel **4008**, which are interpreted by interpreter **4004**, and which do not have to be compiled together with the remaining instructions that make up kernel **4008** prior to execution. Typically memory **144** further includes a scratch memory **4016** taking up address locations **4018**. Scratch memory **4016** can serve a variety of useful purposes. For example, as a storage area for script routine modules received by reader **10** to be interpreted by interpreter **4004**.

The establishing of a script/interpreter programming architecture greatly enhances the versatility of optical reader **10**. Because control circuit **140** can execute script instructions, the functionality of reader **10** can be altered greatly without requiring that an entire new operating program be downloaded into reader **10**. The functionality of reader **10** can be changed simply by making available to reader **10** a script routine module **5000** (FIG. **4**) executable by control circuit **140** during execution kernel **4008**. The script routine module executed by reader **10** may be changed depending on the present application requirements of reader **10**. By allowing a customer to author and execute custom script instructions, the software architecture of FIGS. **3***a* and **3***b* frees the manufacturer/supplier who maintains network **1802**, from having to rewrite the code operating on reader **10** each time a customer's application changes.

Referring to a further aspect of the invention, control circuit **140** is operable in a "host commands" mode and "host routines" mode. In the "host command mode", control circuit **140** executes a script routine module received from host **200** when executing the instructions of kernel **4008**. In the "host routines" mode, control circuit **140** executes a script routine module resident in reader memory **144** when executing the instructions of kernel **4008**. The reader is also operable in a "scanner resident" mode, which may also be termed a "reader resident" mode. In a scanner resident mode, control circuit **140** executes a main operating program which has been compiled and loaded onto reader **10**. When executing a main operating program in a scanner resident mode, control circuit **140** does not receive any script instruction, script routine module, or script routine module identifier when executing instruction of the main operating program or kernel. The software architecture of the operating program of a reader **10** in the scanner resident mode may be of the script/interpreter type as described or else may be of another type (e.g., a fully compiled program without interpreter).

Steps executed by a reader operating in the respective "host commands" mode and in the "host routines" mode are described in greater detail with reference to the flow/block diagram **5500** of FIG. **4**. Reader **10-1** of diagram **5500** is

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depicted as operating in a "host commands" mode while reader **10** of diagram **5500** is depicted as operating in a "host routines" mode.

At step **1** in a "host commands" mode, control circuit **140** sends a request to host **200** requesting that host **200** send to reader **10-1** a script routine module **5000**. Host **200**, in turn, at step **2**, compiles a script routine module comprising a plurality of script instructions, and sends the script routine module **5000** to reader **10-1**. Interpreter **4004** of reader **10-1** then interprets the script routine module and control circuit **140** executes the script routine module **5000**. Alternatively, control circuit **140** in a "host command" mode may be programmed to wait for a script routine module to be received from host **200**, rather than request that a host **200** send a script routine module, as indicated by step (**1**). In other words, step (**1**) can be deleted.

At step A in the "host routines" mode, control circuit **140** of reader **10-3** sends a request to host **200** requesting that host **200** send reader **10** a script routine module identifier **6000**. Host **200**, in turn, at step B, sends reader **10** an identifier **6000** identifying which of a plurality of script routine modules resident in memory **144** should execute. Reader **10-3**, in turn, executes a script routine module corresponding to identifier **6000** sent by host **200**. The word length of the identifier sent by host **200** in the "host routines" mode need only be a fraction (e.g., 1/10th) of the word length of the script routine module sent by host **200** in the "host commands mode." Accordingly, it is seen that selection of the "host routines" mode reduces possible data collisions and speeds up operation of the reader **10-3** and/or network. Control circuit **140** in the "host routines" mode may be programmed to wait for script routine module identifier to be received from host **200**.

A memory map of a reader operating according to a "host routines" mode in one embodiment is shown in FIG. 3*b*. At address locations **4010** memory **144** includes kernel **4008** having an interpreter **4004**. At memory address locations **4030**, memory **144** includes pointers **4032**, and at memory locations **4040**, **4042**, **4044**, **4046** memory **144** includes a plurality of discrete script routine modules **4050**, **4052**, **4054**, **4046** each selectable by establishing of an appropriate program pointer. In the embodiment described with reference to FIG. 3*b*, control circuit **140**, while operating in the "host routines" mode, establishes a pointer to install an appropriate one of script routine modules **4050**, **4052**, **4054**, **4056** so that the selected script routine module **4050** corresponds with the identifier received from host **200**. Prior to their loading in reader memory **144**, modules **4050**, **4052**, **4054**, **4056** may be authored by a user host computer **204**. Host computer **204** may have programmed thereon a program builder toolkit for use in building modules **4050**, **4052**, **4054**, **4056**.

The modes of operation of reader **10** are selected by a user via a user interface **1910**. The user interface can comprise displayed icons displayed on reader display **13***d* of reader **10** as depicted in FIG. 5*a*. Icons **1902**, **1904** can be displayed as part of graphical user interface **1901** in which a pointer device (e.g., trackball, mouse) is used to move an arrow **1906** over a desired icon, and the actuated to effect selection of the mode corresponding to the icon. In a highly useful embodiment of the invention, the user interface utilized to select between the "host command mode" and the "host routines" mode is a user interface incorporated on host **200**. Host **200** can include a user interface such as a graphical user interface **2910** as is indicated by FIG. 5*b*. Further, host **200** can be in communication with a plurality of readers (e.g., readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N) and can be configured such that actuation of a user interface, (e.g., one of icon, e.g., icon **2902**) results in each of the several readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N being programmed in accordance with the same operating mode. Thus, actuation of "host commands" mode icon **240** results in each of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N being programmed to operate on a host commands mode. Likewise, actuation of "host routines" icon **2904** result in each of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N being reprogrammed in a "host routines" mode. Another type of user interface can be used. For example, network **1802** can be configured so that actuation of an appropriate keyboard **13***k* or **213***k* selects a mode of operation. Host **200** can also be programmed so that an actuation of a user initiated command or commands, results in readers of a particular "application group" which may be a subset of the N readers in a network, being programmed in the same way. Application groups are described in U.S. Pat. No. 6,161,760, filed Sep. 14, 1998, entitled "Multiple Application Multiterminal Data Collection Network". For example, host **200** may be utilized to program Application Group **1** to operate in a "host command" mode and Application Group **2** to operate in a "host routines" mode. If readers **10-1**, **10-2**, and **10**-N have been programmed to be part of Application Group **1**, and readers **10-0**, **10-3** have been programmed to be part of Application Group **2**, network **1802** will take on characteristics as illustrated with reference to FIG. **4***b*, wherein host **200** sends readers of Group **1** (readers **10-1**, **10-2**, **10**-N) script routine modules **5000** (sets of script instructions) for execution by control circuit **140** of the reader, and wherein host **200** sends readers of Group **2** (readers **10-0**, **10-3**) identifiers **6000** for identifying at least one of a reader-resident script routine module is to be executed.

The benefits of the respective "host commands" and "host routines" modes of operation of reader **10** will be appreciated as will the benefits of having both of the modes available together.

The "host commands" mode is most useful where host control over operation of several readers **10** is at a premium. Suppose a specific script routine module **5000** must be executed by readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N for only one hour of operation. The script routine module **5000** could be developed using computer **1834** at customer service network **1830** and made available at website of server **1832**. A customer could then download the script routine module **5000** to host **200** via network **1810** or direct link **1811** (FIG. **4**) and contemporaneously, each of several readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N presently in communication with host could be programmed to operate in a "host commands" mode by actuation of icon **2902** or another suitable program method. Each of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N, when executing the instruction of kernel **4008**, will execute the script routine module created at customer service network **1830**. The "host commands" mode (a) provides for complete control by host **200** of reader operation and (b) eliminates the need to send compiled program codes to each of several readers, (e.g., readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N). To change the operation of each of several readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N, all that is needed is a change in a script routine module that is resident in host **200** and available for sending to each of several readers.

The "host routines" mode is most useful where speed is at a premium, and yet host control over operation of several readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N is desired. When several readers operate in a "host routines" mode, host **200** maintains control over the operation of several readers, but

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only selects from preset script routine modules resident in the several readers (e.g., readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N).

In a useful embodiment of the "host routines" mode, control circuit **140** can be configured to execute a string of script routine modules in succession. More specifically, memory **140** can include a plurality of script routine modules, **4050**, **4052**, **4054**, **4056**, and can be configured to execute two or more of the modules in succession in any selected order to define a function different than the function that is defined by control circuit **140** executing a single one of the modules. Accordingly, if a specific function was required of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N for only one hour of operation, personnel utilizing computer **1834** (such as engineers employed by the manufacturer of reader **10**) at customer service center network **1830** could identify a string of subroutine modules within readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N which, when executed together in succession, satisfied the required function. For example, modules **4050**, **4052**, **4056** executed in the order of (1) **4050**; (2) **4056**; (3) **4050**, could define a new function. From the string of script routine modules, a corresponding string of identifiers could be created and transmitted from computer **1834** to host **200** via network **1810**. A user of host **200** could reprogram all of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N in communication thereto in accordance with a "host routines" mode operation simply by actuation of routines icon **2904** as depicted in FIG. **5***b*. Operating in accordance with the host routines mode, all of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N would execute a string of script routine modules identified at customer service network **1830** as being capable of performing the required custom-made function.

The availability of both of the "host commands" mode and the "host routines" modes allows readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N to be customized to the end that the needs of a customer can be satisfied. If a customer demands high accuracy, a highly specialized operating routine, and a host control of operation of one or more reader, the "host commands" mode can be selected. If a customer demands high-speed operation in a custom developed application, the "host routines" mode can be selected. If one of the modes of operation fails to satisfy the needs of a customer, the other mode of operation can be tried. For example, if during the course of operation in the "host routines" mode it is found that one or more of readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N configured to operate in the mode had not previously been updated to include thereon all of the script routine modules **4050**, **4052**, **4054**, **4056** specified by the script routine module identifier **6000** or identifier string sent by host **200** to reader **10**, or if a required reader function cannot be satisfied by selection of one or more script routine modules resident on a reader, a user may select the "host commands" mode of operation so that all of the readers **10-0**, **10-1**, **10-2**, **10-3**, **10**-N satisfy the required function.

An example of the invention is described with reference to the correspondence memory map of FIG. **6** in which various sections of pseudocode corresponding to an exemplary kernel and exemplary script routine modules are shown in association with the memory map originally described relative to FIG. **3***b*.

In the example of FIG. **6**, a kernel utilizing address locations **4010** may simply wait for script instructions or a script routine module (a series of script instructions) as is indicated by one-line pseudocode program **7010**.

Referring to further aspects of the memory map of FIG. **6**, address locations **4040** may contain a script routine module for displaying a particular error message on display **13***d* as is indicated by pseudocode **7040**. Further address locations **4042** may contain a script routine module for conducting an inventory application as is indicated by pseudocode **7042**. Still further, address locations **4044** may contain a script routine module for conducting a shipping application as is indicated by pseudocode **7044**.

In "host commands" mode, control circuit **140** of one or several like programmed readers interprets and executes a string of script instructions, (i.e., script routine modules **5000** received from host **200**). For example, control circuit **140** of one or several like programmed readers, when operating in a "host commands" mode, may execute a string of instructions such as instructions corresponding to pseudocode **8040** or pseudocode **8042**, or an entirely different script routine module customer authored by a user utilizing host **200** or reader **10**. It is understood that when instructions corresponding to pseudocode **8040**, pseudocode **8042**, and pseudocode **8044** are executed by control circuit **140**, various built in firmware functions of control circuit **140** are executed.

In addition to or as part of the GUI driver menu selector interface described relative to FIGS. **5***a* and **5***b*, reader **10** may be driven into "host routines" mode by the sending of a specialized script instruction from host **200** to reader **10**. Specifically, identifier **5000** may comprise a script instruction including pointer information, which is interpreted and executed by control circuit **140** to select and execute a selected one of the script routine modules, which has been loaded into the memory locations **4040**, **4042**, **4044**. An identifier **5000**, for example, may comprise the compiled data corresponding to the pseudocode script instruction EXECUTE (INVENTORY). On receipt of the identifier, reader **10** executes the corresponding script routine module, which in the example of FIG. **6**, corresponds to pseudocode **7042**.

Referring to the user interface of FIG. **7**, a user may build a script routine module utilizing an appropriate toolkit and GUI interface loaded onto host **200**. When a user has authored a program in a user understandable language as in the pseudocode **8042** of FIG. **7**, the user may select various control buttons. For example, actuation of RUN button **9002** may result in the authored program being compiled and formatted for sending to reader **10** or several readers **10** for interpretation and execution by reader **10** or several readers **10**. Actuation of SAVE button **9004** may result in the authored program represented by pseudocode **9002** being compiled, formatted and loaded into a designated script routine module memory location of a reader **10** or readers **10** (e.g., location **4042**) so that the program is executed by reader **10** when reader **10** operates in a "host routines" mode as described herein.

While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawing, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims.

We claim:

1. A method to create a custom function in an optical reader comprising the steps of:

providing a hand held optical reader having a host routines mode and a plurality of script routine modules;

providing a host computer to communicate with the optical reader;

providing a computer to order script routine modules into lists that can be executed in succession by the optical reader;

identifying a string of the script routine modules using the computer such that when said string of script routine modules are executed together in succession said string of script routine modules define a function;

generating a string of identifiers representing the string of script routine modules on the computer;

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transmitting the string of identifiers from the computer to the host computer;

transmitting the string of identifiers from the host computer to one or more optical readers set to the host routines mode; and

executing the custom function on at least one of the optical readers as the execution order of a selected list of script routine modules.

2. The method of claim **1**, to create a custom function wherein the step of identifying a string of the script routine modules comprises identifying a string of the script routine modules using the computer such that when the script routine modules are executed together in succession said string of script routine modules define a function to display a particular error message on an optical reader display.

3. The method of claim **1**, to create a custom function wherein the step of identifying a string of the script routine modules comprises identifying a string of the script routine modules using the computer such that when the script routine modules are executed together in succession said string of script routine modules define a function to conduct an inventory application.

4. The method of claim **1**, to create a custom function wherein the step of identifying a string of the script routine modules comprises identifying a string of the script routine modules using the computer such that when the script routine modules are executed together in succession said string of script routine modules define a function to conduct a shipping application.

5. The method of claim **1**, to create a custom function wherein the step of transmitting the string of identifiers from the host computer to one or more optical readers comprises transmitting the string of identifiers from the host computer to one or more optical readers set to the host routines mode wherein the script routine modules identified by the string of identifiers are resident in the one or more optical readers.

6. The method of claim **1**, to create a custom function wherein the step of executing the custom function comprises executing the custom function on at least one of the optical readers as the execution order of a selected list of script routine modules wherein a control circuit within the optical reader executes the script routine modules resident in a memory in the optical reader.

7. The method of claim **6**, to create a custom function wherein the step of executing the custom function comprises executing the custom function on at least one of the optical readers as the execution order of a selected list of script routine modules wherein a control circuit within the optical reader executes script routine modules resident in a memory in the optical reader and the control circuit selects each successive script routine modules by use of a program pointer.

8. The method of claim **1**, to create a custom function further comprising the step of sending a request to the host computer requesting the script identifiers before the step of transmitting the string of identifiers from the host computer.

9. A method to create a custom function in an optical reader comprising the steps of:

providing a hand held optical reader having a host command mode;

providing a host computer to communicate with the optical reader and to send one or more script routine modules to the optical reader set to the host command mode;

identifying one or more script routine modules to be transmitted to the optical reader;

transmitting the one or more script routine modules from the host computer to one or more optical readers set to the host command mode such that the script routine modules are executed together in succession by the optical reader as a custom function; and

executing the custom function on at least one of the optical readers.

10. The method of claim **9**, to create a custom function wherein the step of providing a hand held optical reader comprises providing a hand held optical reader having a host command mode and a control circuit.

11. The method of claim **10**, to create a custom function further comprising the step of sending a request to the host computer to send a script routine module to the reader before the step of transmitting the one or more script routine modules.

12. The method of claim **9**, to create a custom function wherein the step of providing a hand held optical reader comprises providing a hand held optical reader having a host command mode, a control circuit, and an interpreter.

13. The method of claim **12**, to create a custom function wherein the step of executing the custom function comprises executing the custom function on at least one of the optical readers by interpreting the one or more script routine modules in the optical reader using the interpreter, and executing the interpreted script routine modules with the control circuit to perform the custom function.

14. The method of claim **13**, to create a custom function wherein the step of executing the custom function comprises executing the custom function on at least one of the optical readers by interpreting the one or more script routine modules in the optical reader using the interpreter, and executing the interpreted script routine modules with the control circuit by further executing one or more firmware functions built into optical reader to perform the custom function.

15. The method of claim **9**, to create a custom function wherein the step of identifying the one or more script routine modules comprises identifying the one or more script routine modules to be transmitted to the optical reader in the host command mode following an unsuccessful attempt to create the custom function using a host routines mode wherein one or more of the needed script routine modules is not resident in the optical reader.

16. The method of claim **15**, to create a custom function wherein the step of identifying the one or more script routine modules comprises identifying the one or more script routine modules to be transmitted to the optical reader in the host command mode following an unsuccessful attempt to create the custom function using a host routines mode wherein one or more of the needed script routine modules is not resident in the optical reader, and after the needed script routine modules are loaded into the reader in the host command mode and after the reader is returned to the host routines mode, a pointer is established to associate each of the selected script routine modules with an identifier.

17. The method of claim **9**, to create a custom function wherein the step of identifying the one or more script routine modules comprises identifying the one or more script routine modules to be transmitted to the optical reader to display a particular error message on an optical reader display.

18. The method of claim **9**, to create a custom function wherein the step of identifying the one or more script routine modules comprises identifying the one or more script routine modules to be transmitted to define a function to conduct an inventory application.

19. The method of claim **9**, to create a custom function wherein the step of identifying the one or more script routine

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modules comprises identifying the one or more script routine modules to be transmitted to the optical reader to define a function to conduct a shipping application.

20. A hand held optical reader including:

a control circuit configured to control an image sensor and including a memory, a processor and firmware and where said processor is configured to execute instructions stored within said memory and said firmware;

a main operating program including a plurality of said instructions configured for execution by said processor;

a script interpreter program including a plurality of said instructions configured for execution by said processor, said script interpreter program is configured to interpret and execute commands communicated to said memory from another computer after execution of said main operating program; and where said commands direct the execution of firmware functions stored within said firmware.

* * * * *

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Xian et al.

(10) Patent No.: US 8,752,766 B2
(45) Date of Patent: Jun. 17, 2014

(54) **INDICIA READING SYSTEM EMPLOYING DIGITAL GAIN CONTROL**

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(73) Assignee: **Metrologic Instruments, Inc.**, Blackwood, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/888,884**

(22) Filed: **May 7, 2013**

(65) **Prior Publication Data**

US 2013/0292474 A1 Nov. 7, 2013

Related U.S. Application Data

(60) Provisional application No. 61/632,423, filed on May 7, 2012.

(51) **Int. Cl.**
G06K 7/10 (2006.01)

(52) **U.S. Cl.**
USPC **235/462.26**; 235/375

(58) **Field of Classification Search**
USPC 235/462.26, 462.45, 472.45, 472.01, 235/375, 462.25
See application file for complete search history.

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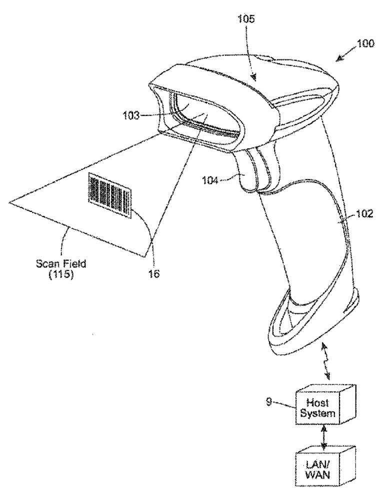
Primary Examiner — Edwyn Labaze
(74) *Attorney, Agent, or Firm* — Additon, Higgins, Pendleton & Ashe, P.A.

(57) **ABSTRACT**

A laser scanning code symbol reading system includes an analog scan data signal processor for producing digitized data signals, wherein during each laser beam scanning cycle, a light collection and photo-detection module generates an analog scan data signal corresponding to a laser scanned code symbol, an analog scan data signal processor/digitizer processes the analog scan data signal to generate digital data signals corresponding thereto, and a synchronized digital gain control module automatically processes the digitized data signals in response to start of scan (SOS) signals generated by a SOS detector. The synchronized digital gain control module generates digital control data which is transmitted to the analog scan data signal processor for use in controlling the gain of at least one signal processing stage in the light collection and photo-detection module and/or analog scan data signal processor, during the corresponding laser beam scanning cycle.

20 Claims, 18 Drawing Sheets



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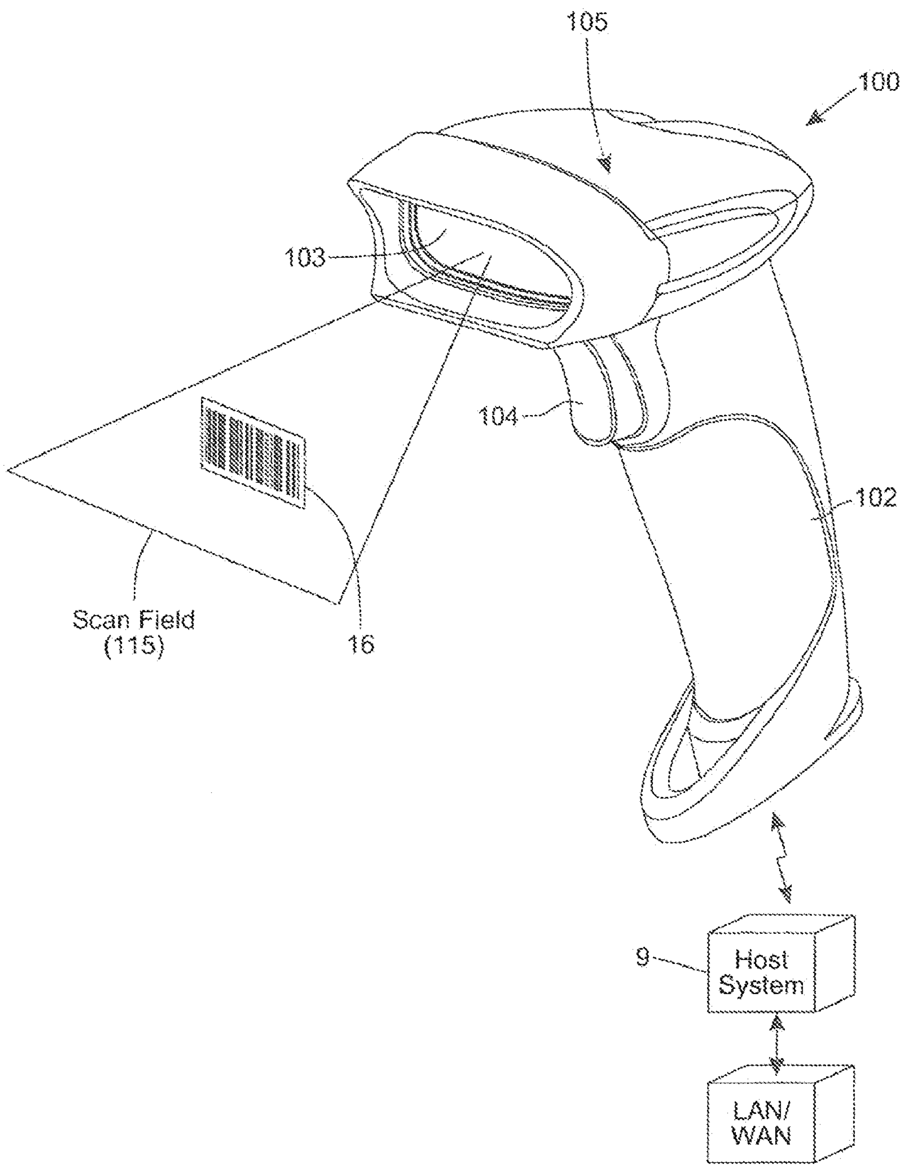

FIG. 1

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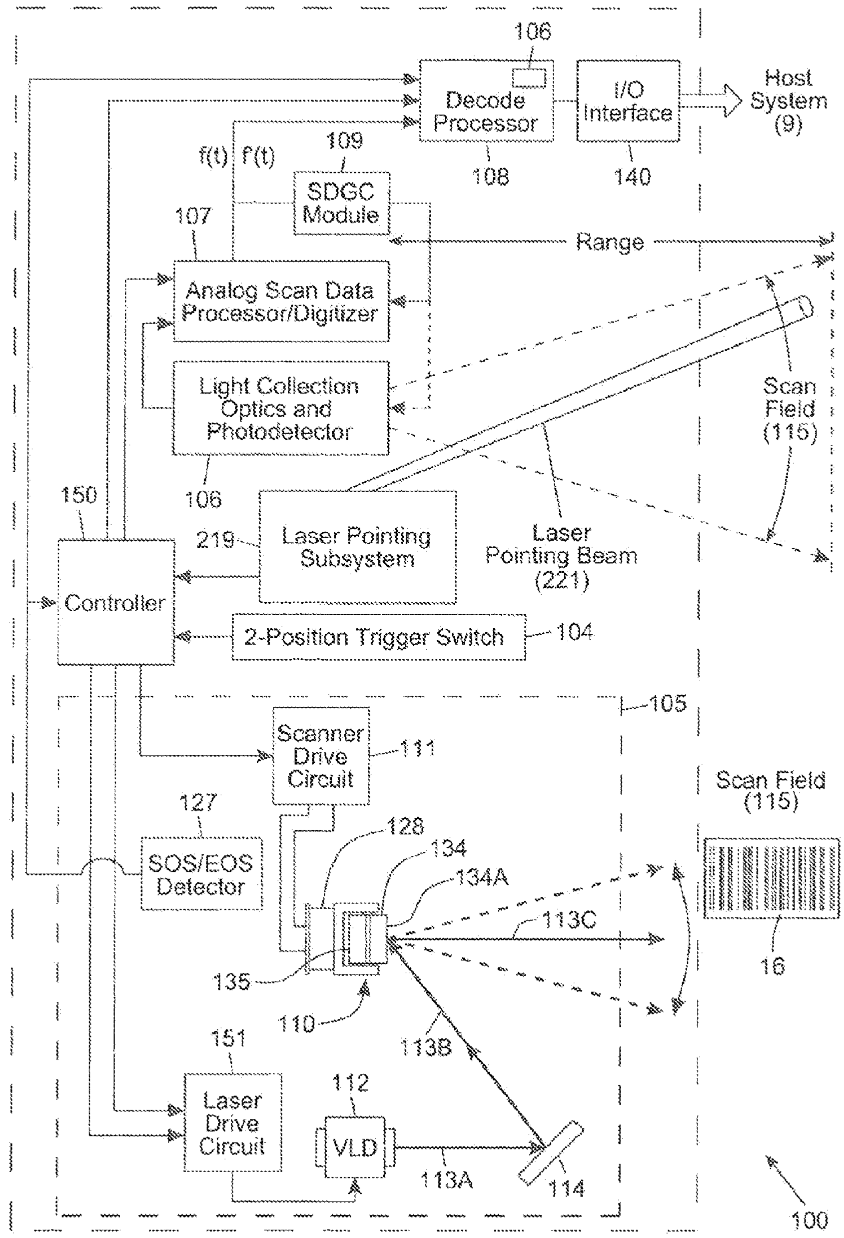

106
Decode Processor
I/O Interface
Host System (9)
108
140
f(t)
f'(t)
109
SDGC Module
107
Range
Analog Scan Data Processor/Digitizer
Light Collection Optics and Photodetector
Scan Field (115)
106
150
Laser Pointing Subsystem
219
Laser Pointing Beam (221)
Controller
2-Position Trigger Switch
104
105
Scanner Drive Circuit
111
127
Scan Field (115)
SOS/EOS Detector
128
134
134A
113C
16
135
110
113B
151
Laser Drive Circuit
112
VLD
113A
114
100

FIG. 2

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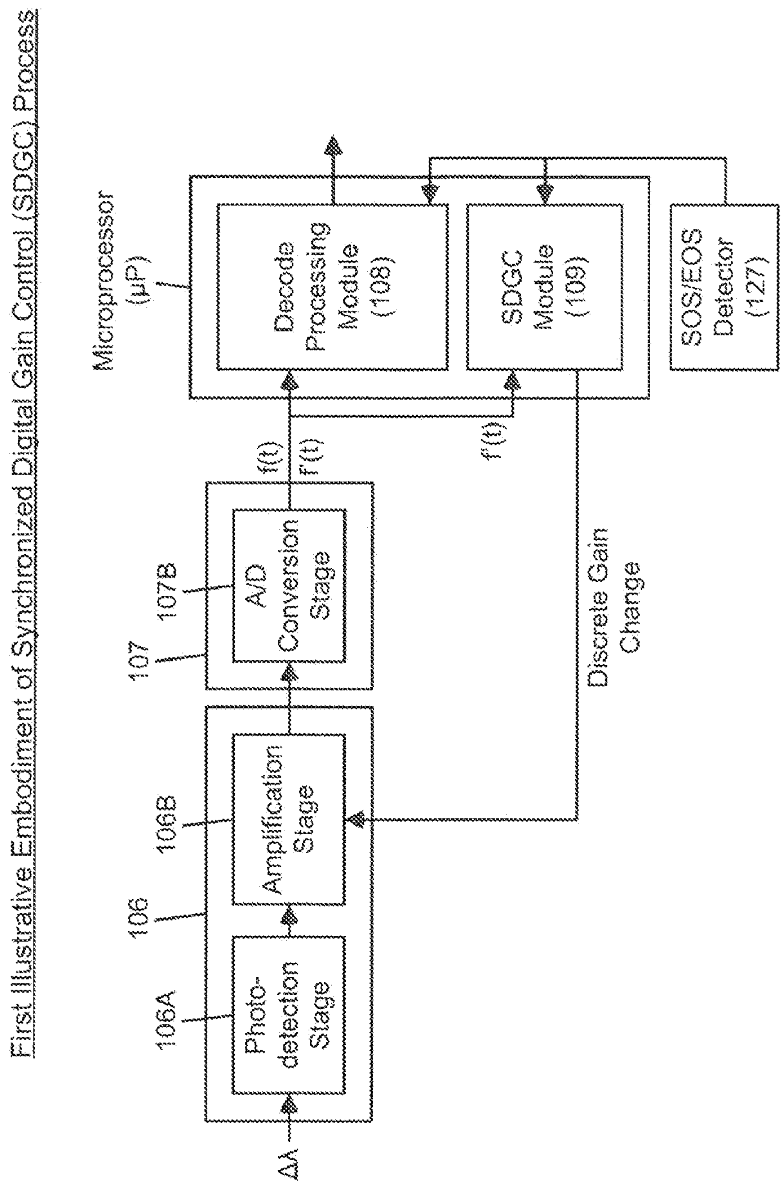
First Illustrative Embodiment of Synchronized Digital Gain Control (SDGC) Process
Microprocessor (μP)
Decode Processing Module (108)
SDGC Module (109)
SOS/EOS Detector (127)
f(t)
f'(t)
f'(t)
107
107B
A/D Conversion Stage
Discrete Gain Change
106
106B
Amplification Stage
106A
Photo-detection Stage
Δλ

FIG. 3A

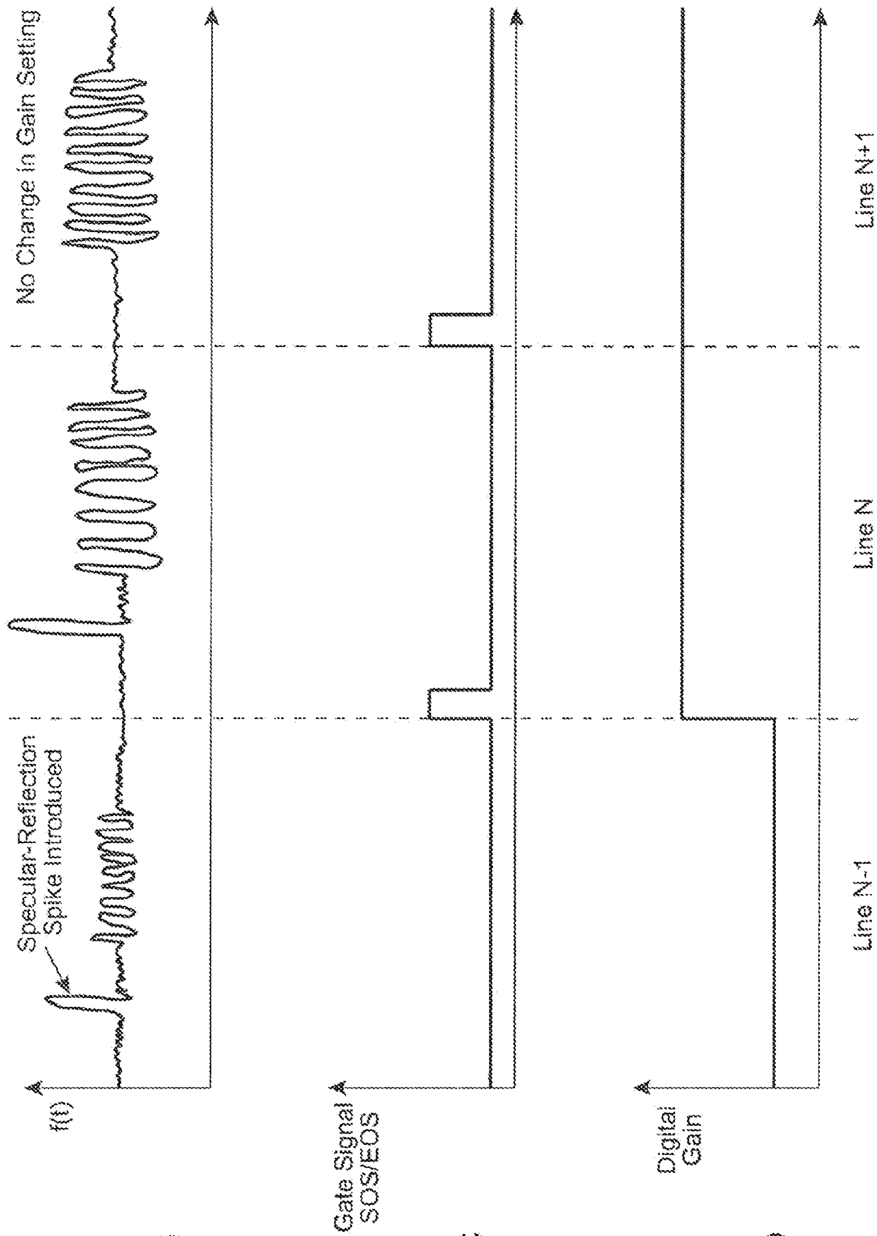

FIG. 3B

FIG. 3C

FIG. 3D

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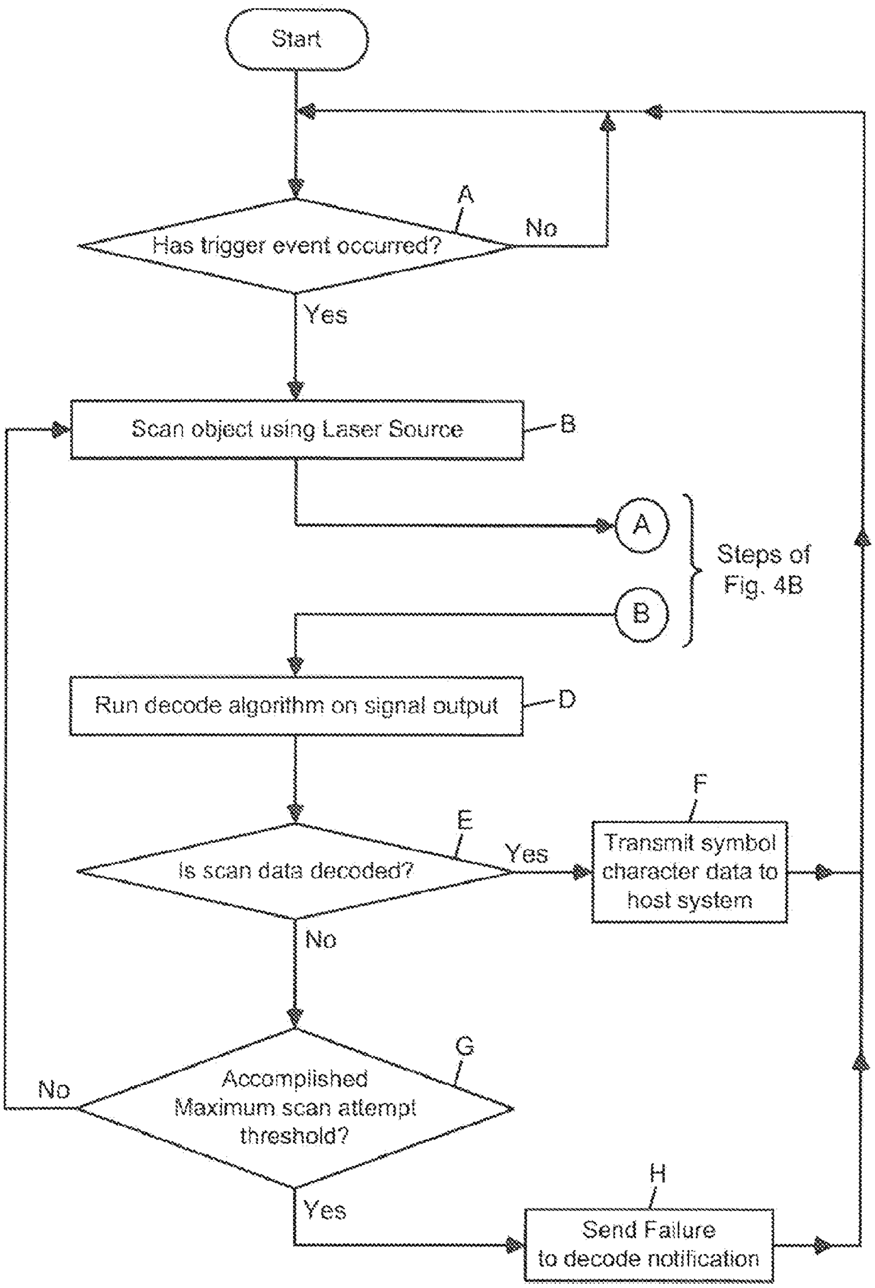

Start
A
Has trigger event occurred?
No
Yes
Scan object using Laser Source
B
A
B
Steps of Fig. 4B
Run decode algorithm on signal output
D
E
Is scan data decoded?
Yes
F
Transmit symbol character data to host system
No
G
Accomplished Maximum scan attempt threshold?
No
Yes
H
Send Failure to decode notification

FIG. 4A

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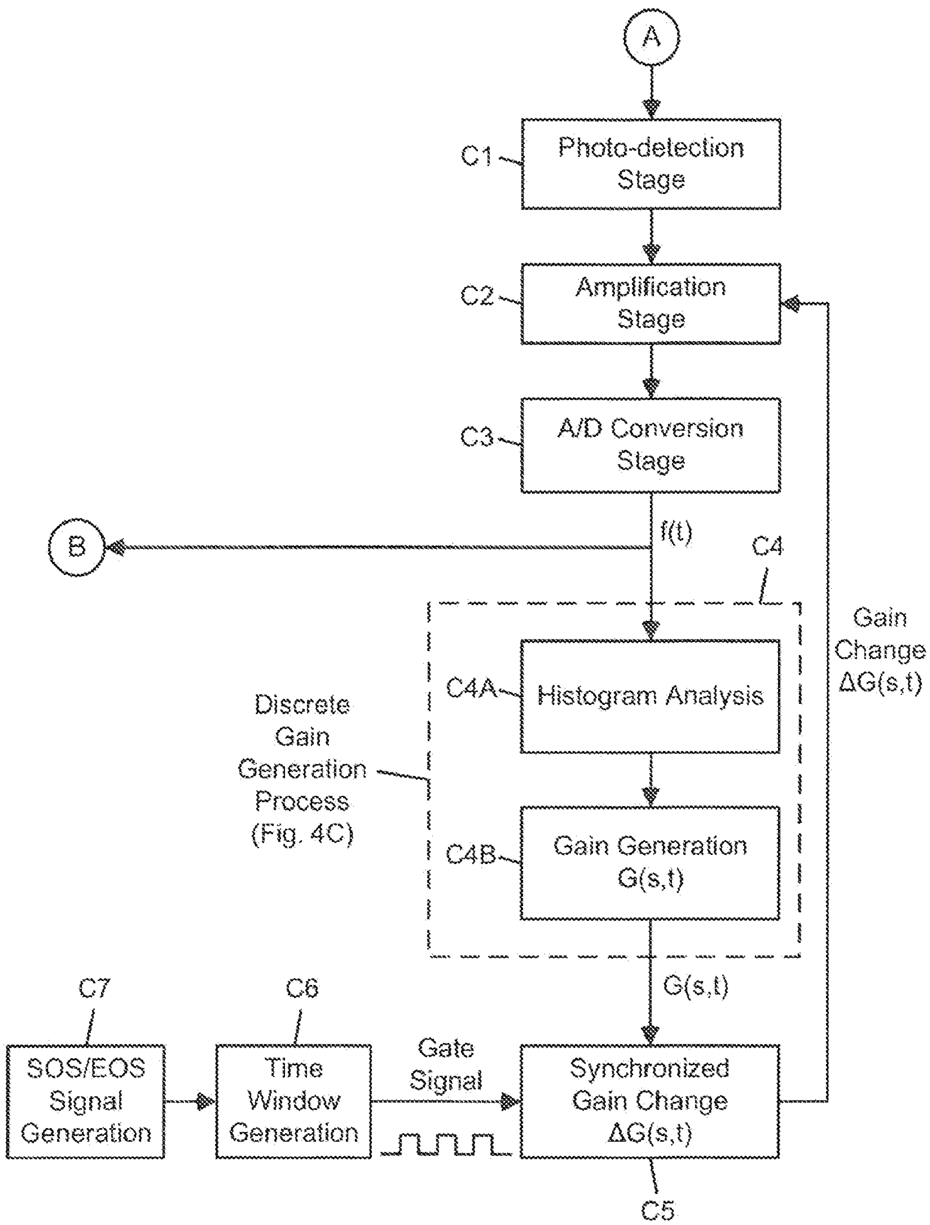
A
C1
Photo-detection Stage
C2
Amplification Stage
C3
A/D Conversion Stage
B
f(t)
C4
Gain Change ΔG(s,t)
C4A
Histogram Analysis
Discrete Gain Generation Process (Fig. 4C)
C4B
Gain Generation G(s,t)
G(s,t)
C7
C6
SOS/EOS Signal Generation
Time Window Generation
Gate Signal
Synchronized Gain Change ΔG(s,t)
C5

FIG. 4B

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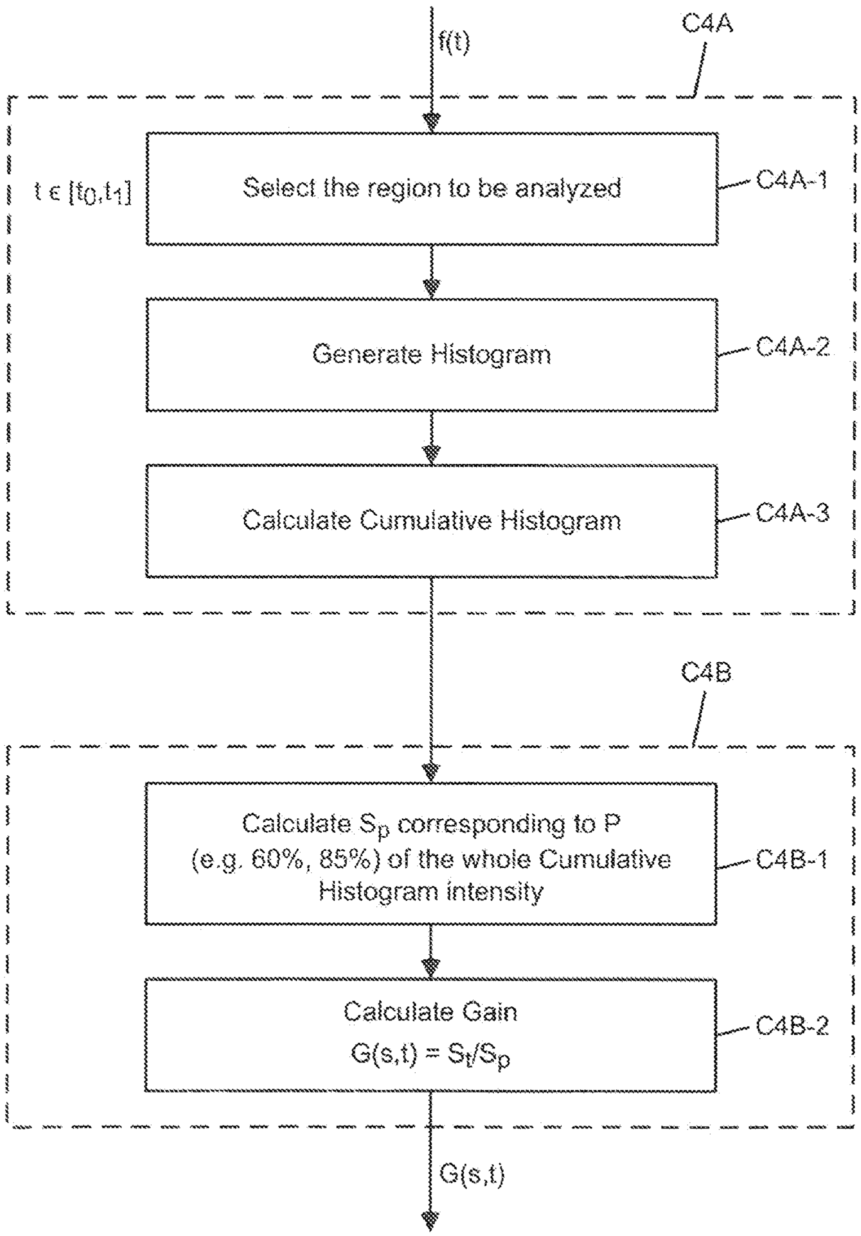
f(t)
C4A
t ϵ [t0,t1]
Select the region to be analyzed
C4A-1
Generate Histogram
C4A-2
Calculate Cumulative Histogram
C4A-3
C4B
Calculate Sp corresponding to P
(e.g. 60%, 85%) of the whole Cumulative
Histogram intensity
C4B-1
Calculate Gain
G(s,t) = St/Sp
C4B-2
G(s,t)

FIG. 4C

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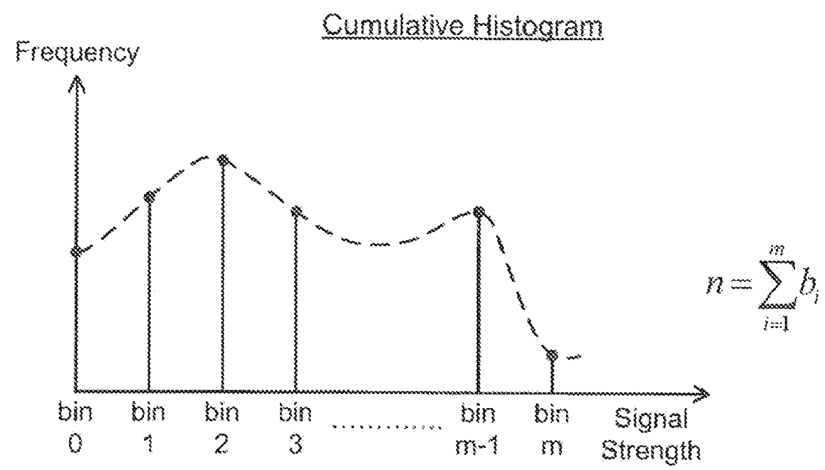

FIG. 5A

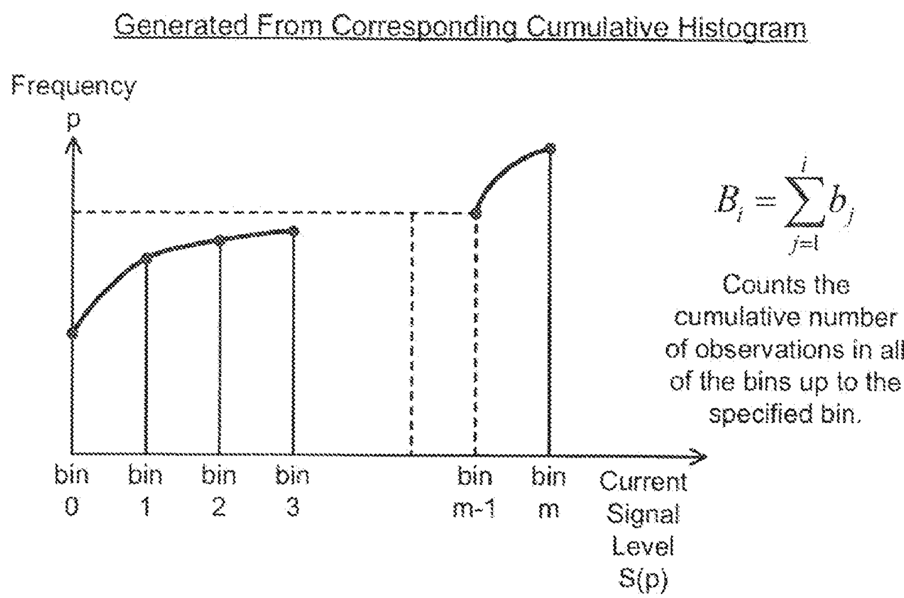

FIG. 5B

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Second Illustrative Embodiment of Synchronized Digital Gain Control (SDGC) Process

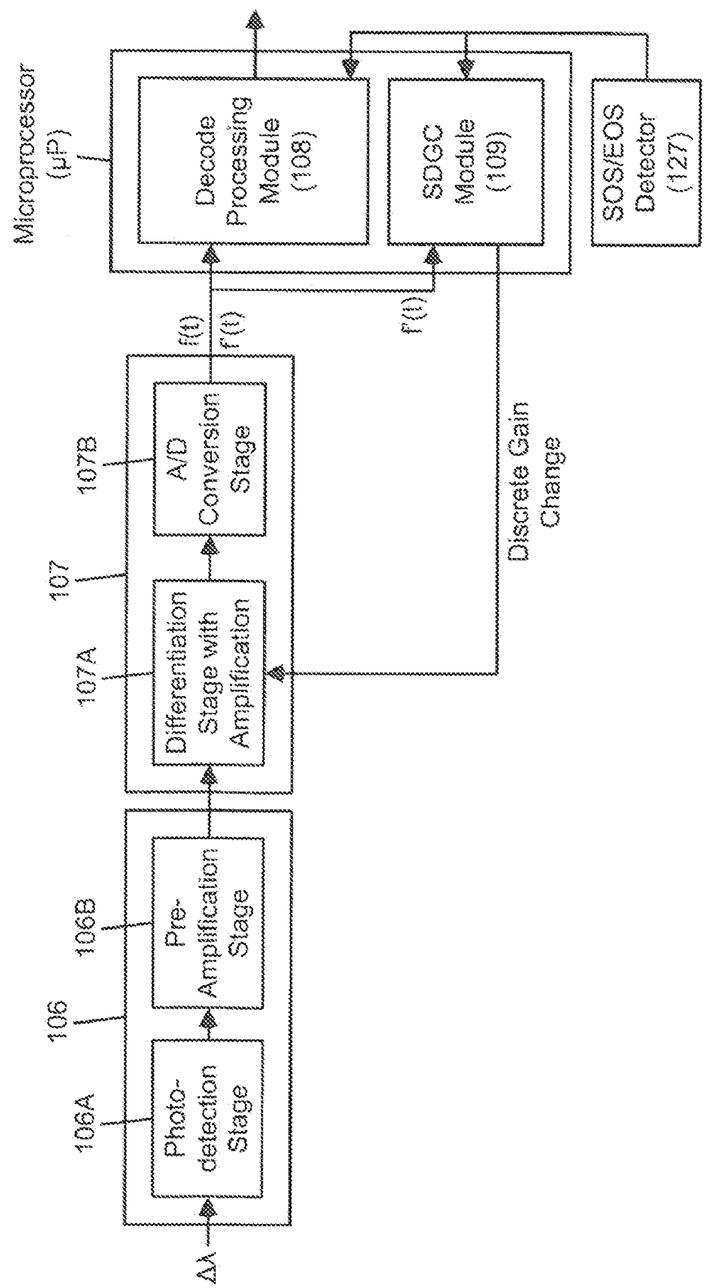

FIG. 6A

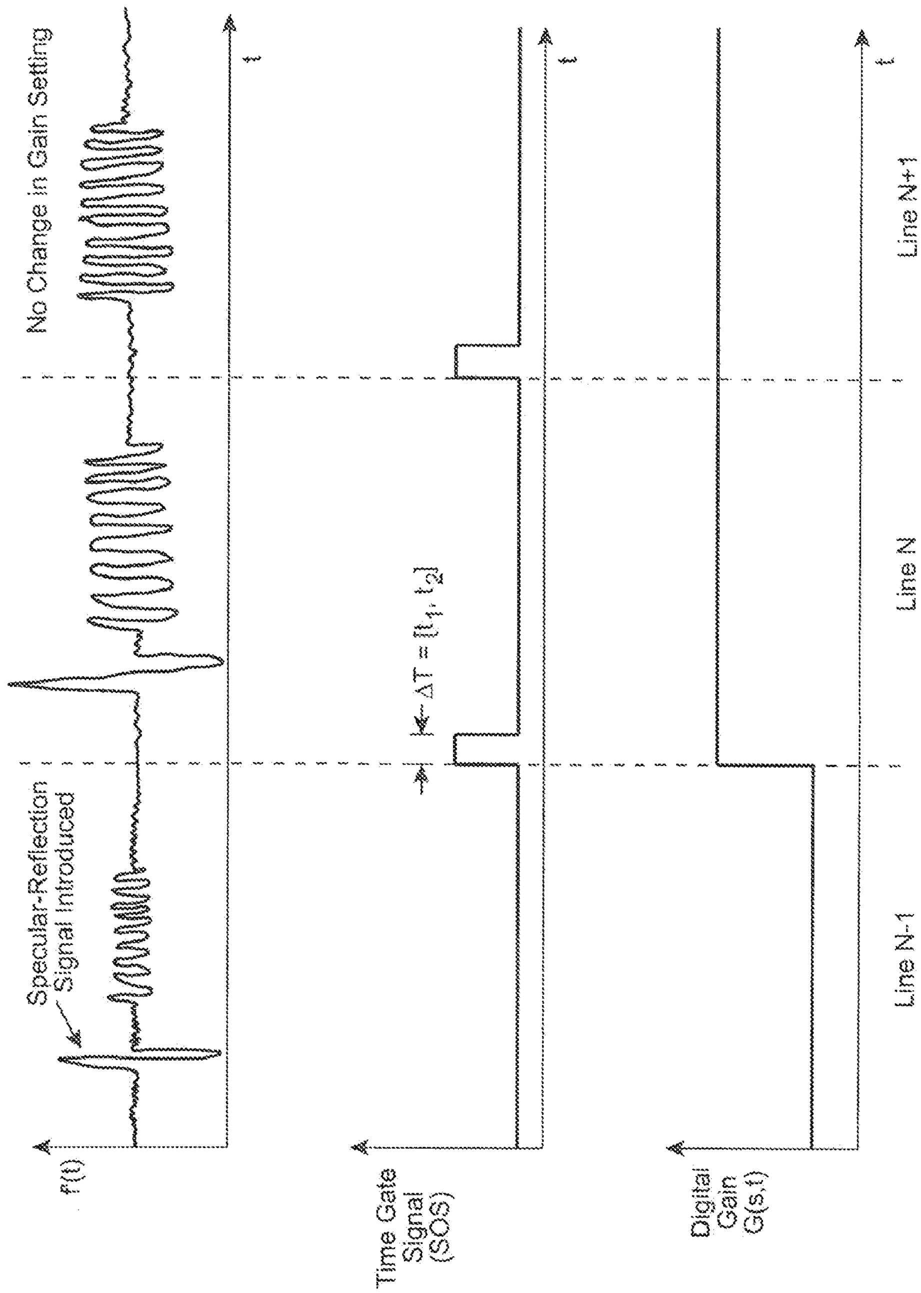

FIG. 6B

FIG. 6C

FIG. 6D

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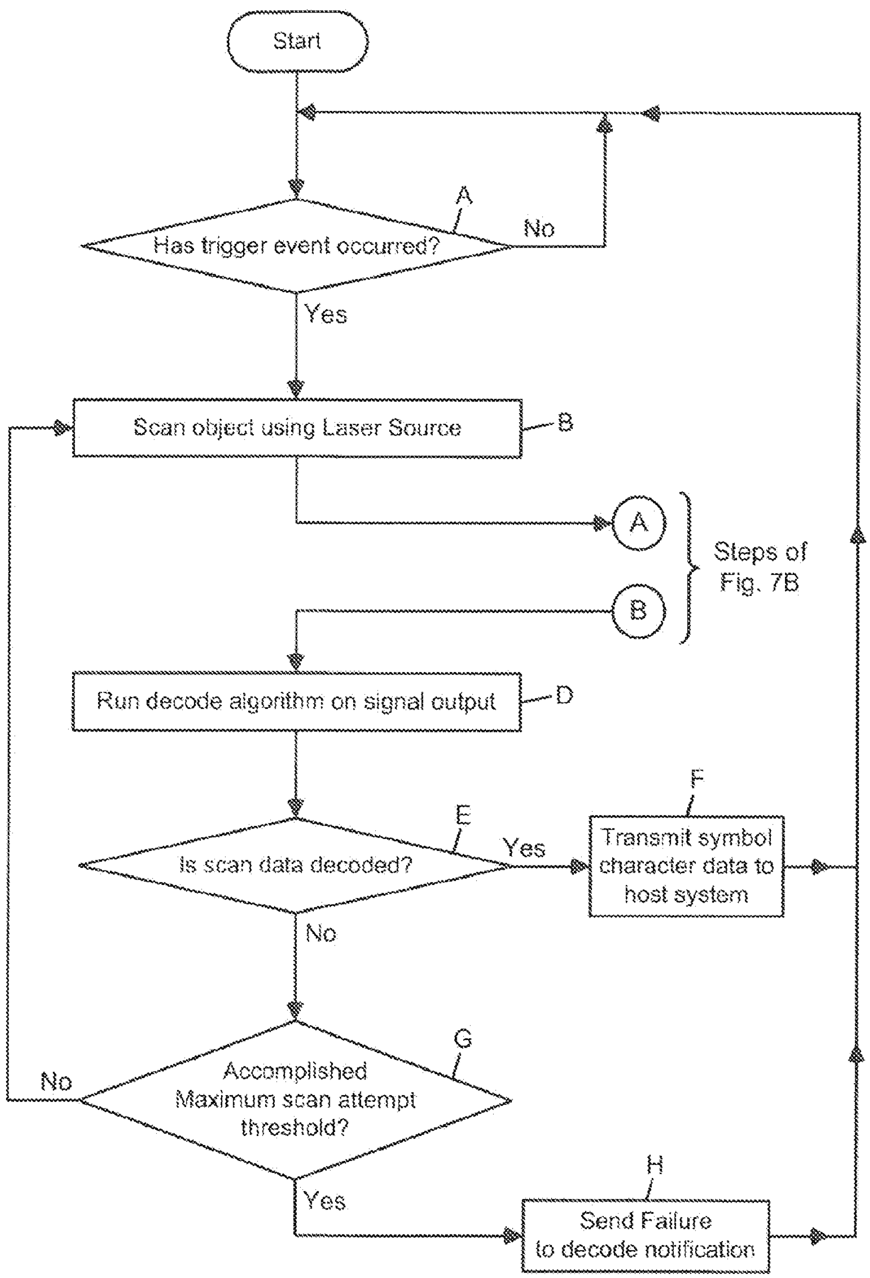

Start
A
Has trigger event occurred?
No
Yes
Scan object using Laser Source
B
A
B
Steps of Fig. 7B
Run decode algorithm on signal output
D
E
Is scan data decoded?
Yes
F
Transmit symbol character data to host system
No
G
Accomplished Maximum scan attempt threshold?
No
Yes
H
Send Failure to decode notification

FIG. 7A

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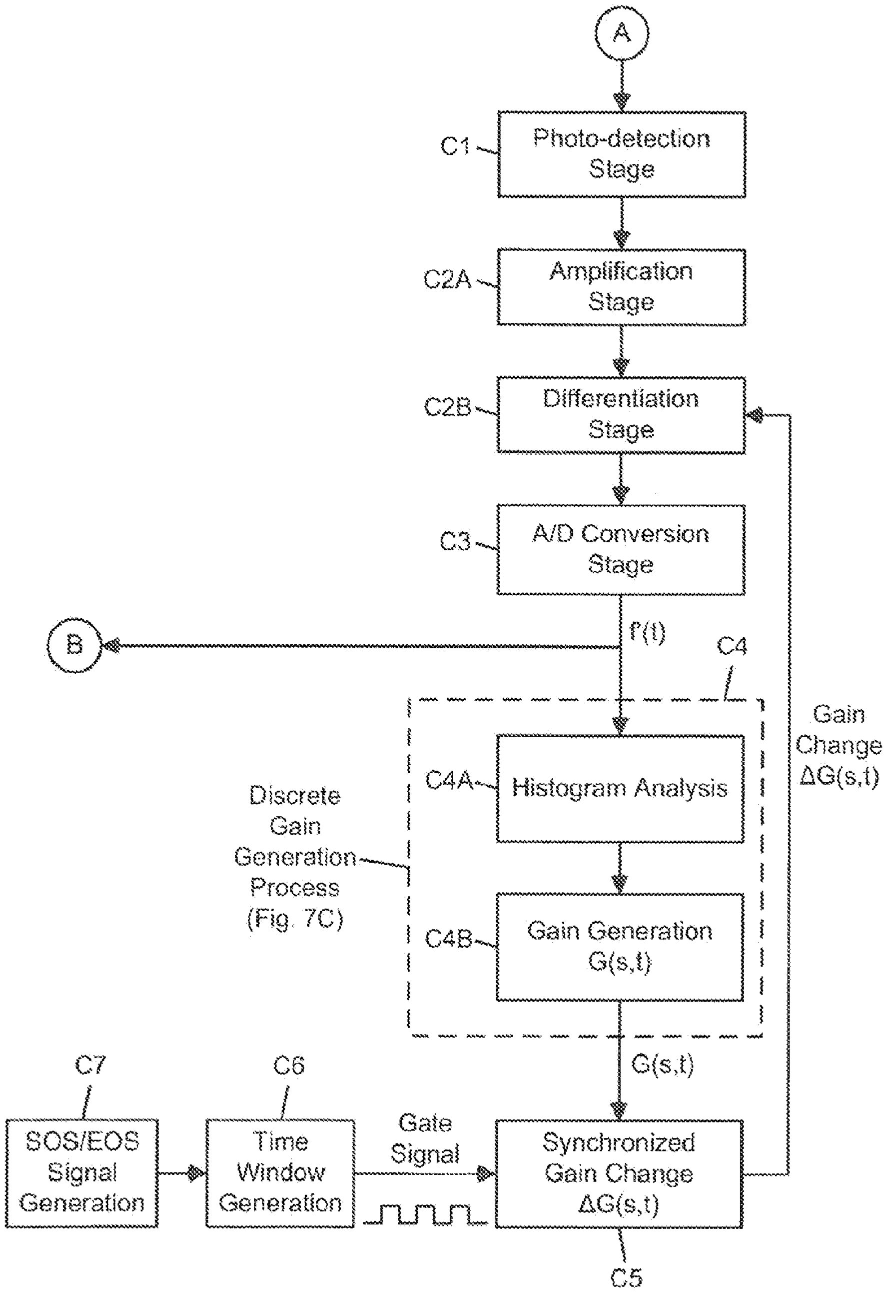

A
C1
Photo-detection Stage
C2A
Amplification Stage
C2B
Differentiation Stage
C3
A/D Conversion Stage
f'(t)
B
C4
Gain Change ΔG(s,t)
Discrete Gain Generation Process (Fig. 7C)
C4A
Histogram Analysis
C4B
Gain Generation G(s,t)
G(s,t)
C7
C6
SOS/EOS Signal Generation
Time Window Generation
Gate Signal
Synchronized Gain Change ΔG(s,t)
C5

FIG. 7B

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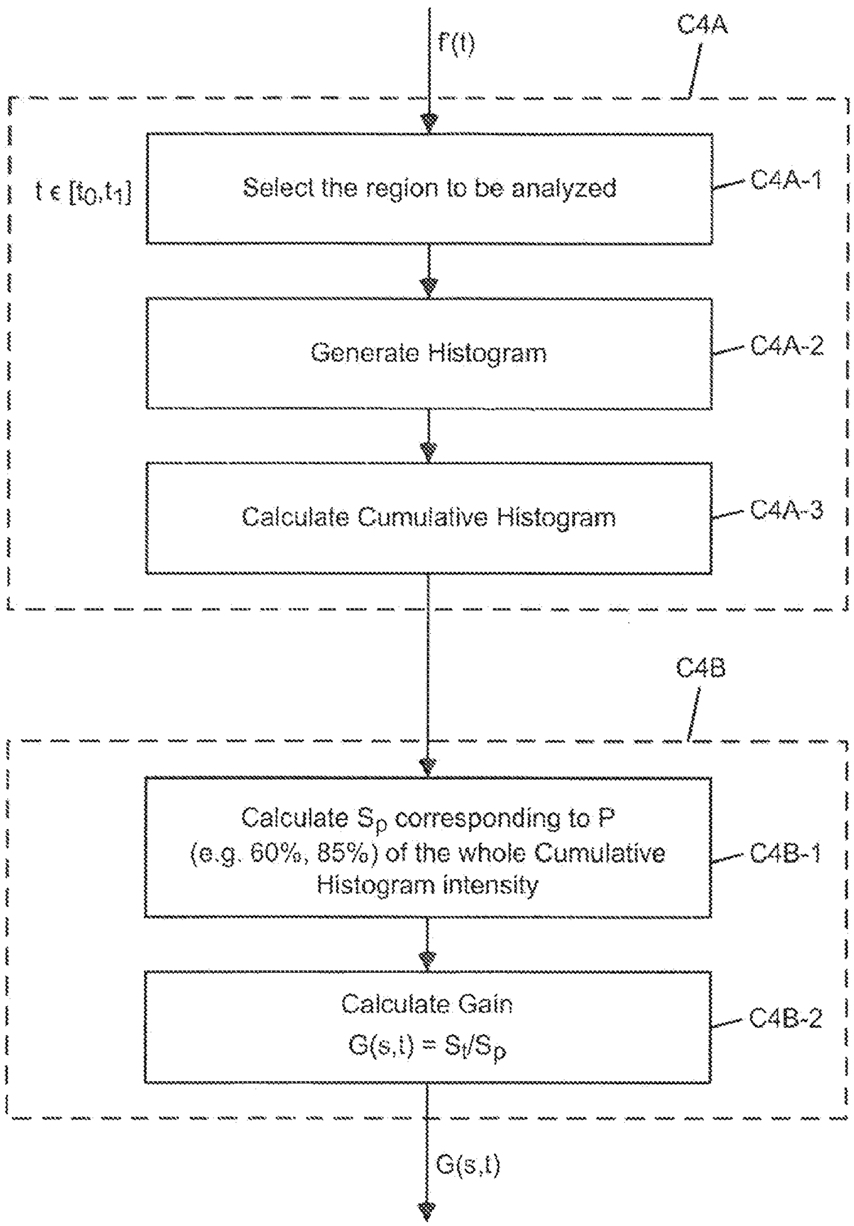

f'(t)
C4A
t ϵ [t0,t1]
Select the region to be analyzed
C4A-1
Generate Histogram
C4A-2
Calculate Cumulative Histogram
C4A-3
C4B
Calculate Sp corresponding to P (e.g. 60%, 85%) of the whole Cumulative Histogram intensity
C4B-1
Calculate Gain G(s,t) = St/Sp
C4B-2
G(s,t)

FIG. 7C

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Third Illustrative Embodiment of Synchronized Digital Gain Control (SDGC) Process

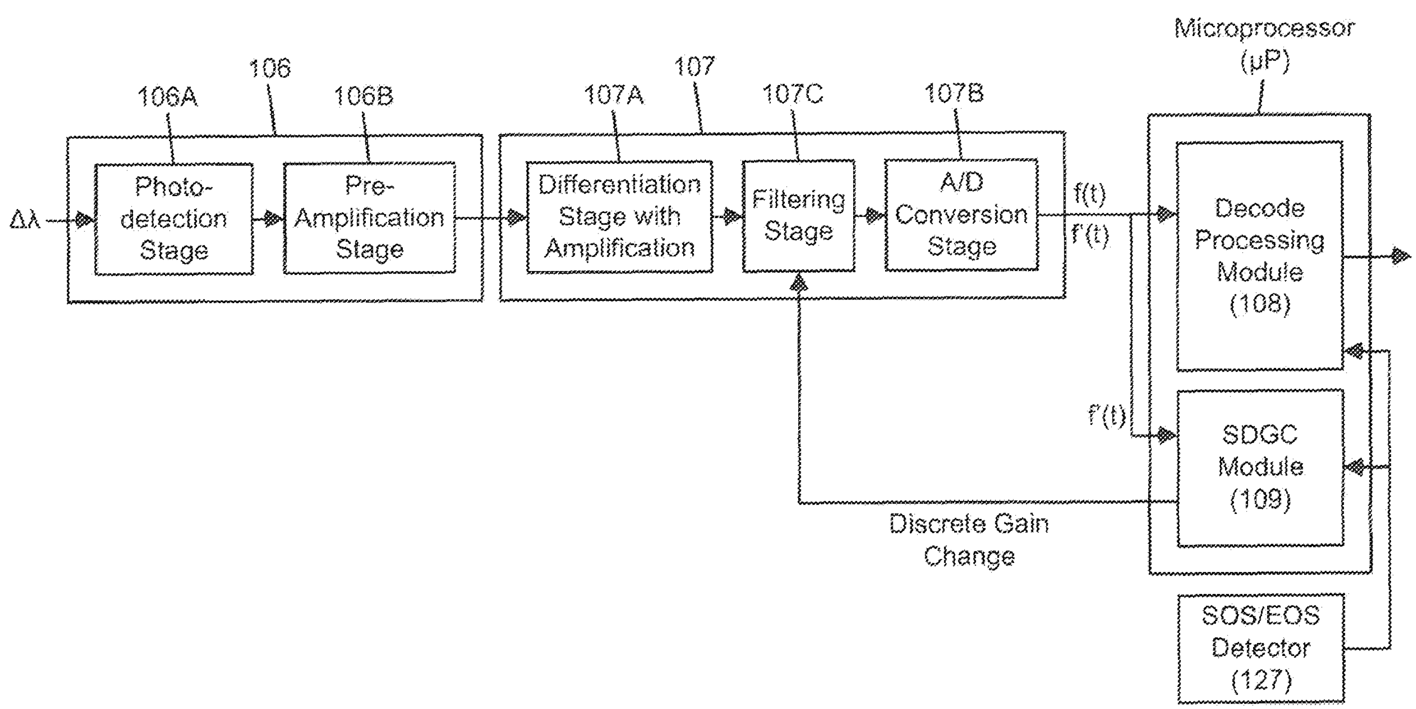

FIG. 8A

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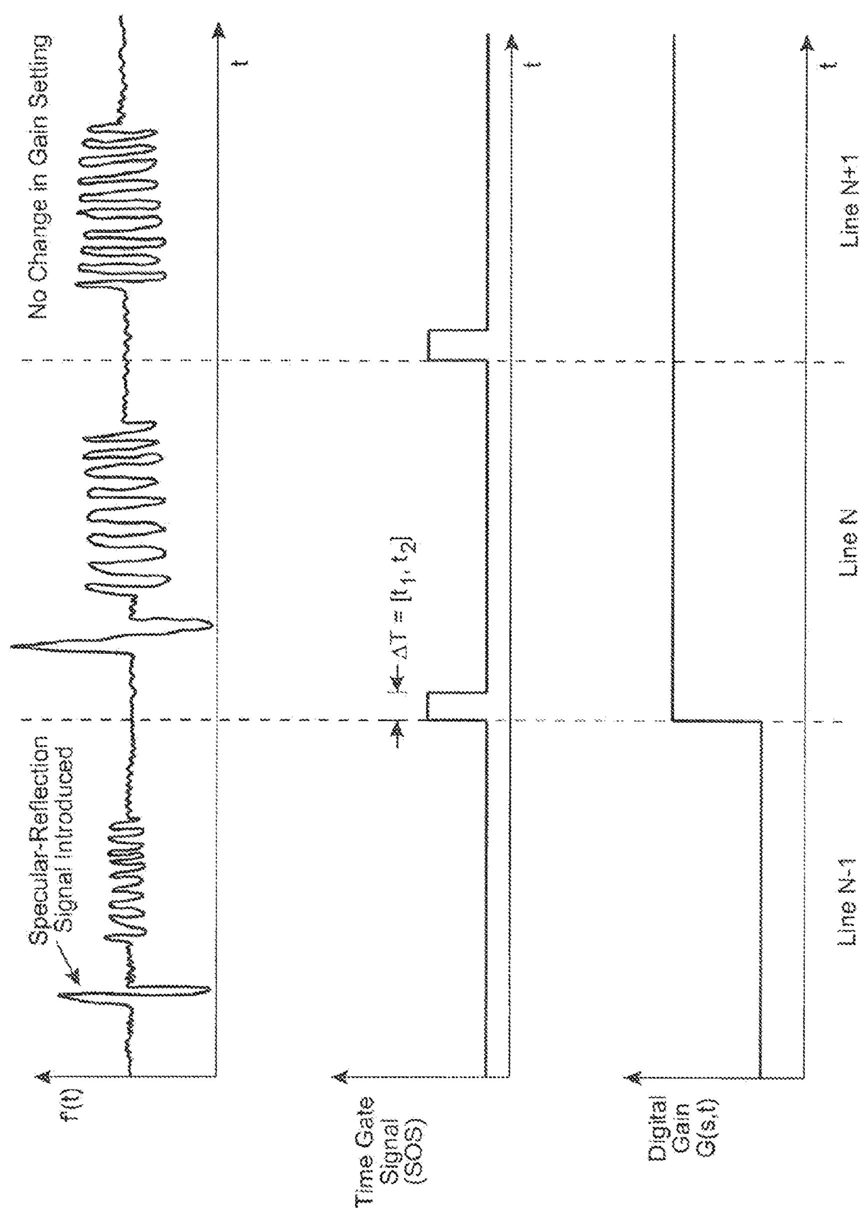

FIG. 8B

FIG. 8C

FIG. 8D

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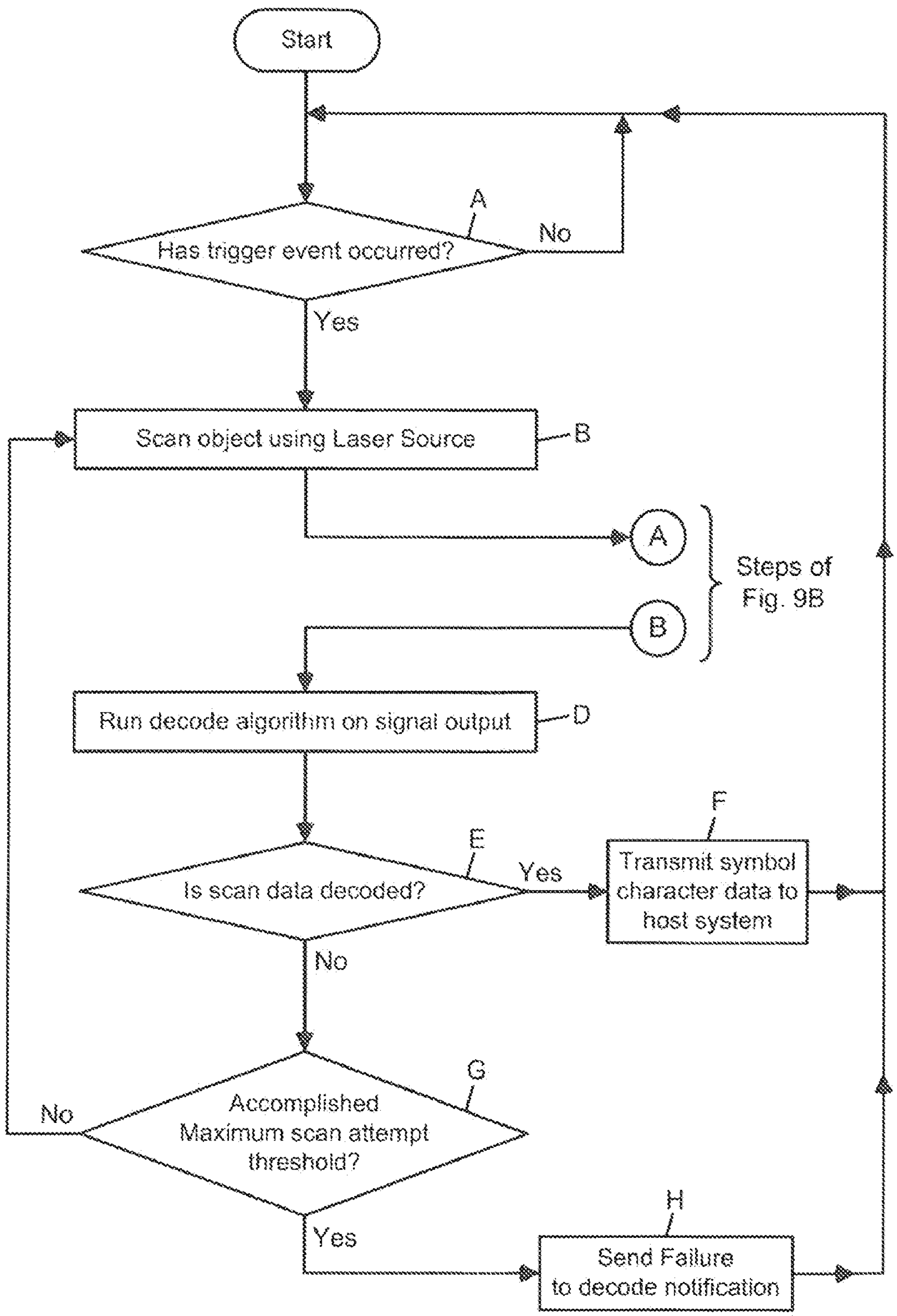
Start
Has trigger event occurred?
A
No
Yes
Scan object using Laser Source
B
A
B
Steps of Fig. 9B
Run decode algorithm on signal output
D
Is scan data decoded?
E
Yes
F
Transmit symbol character data to host system
No
Accomplished Maximum scan attempt threshold?
G
No
Yes
H
Send Failure to decode notification

FIG. 9A

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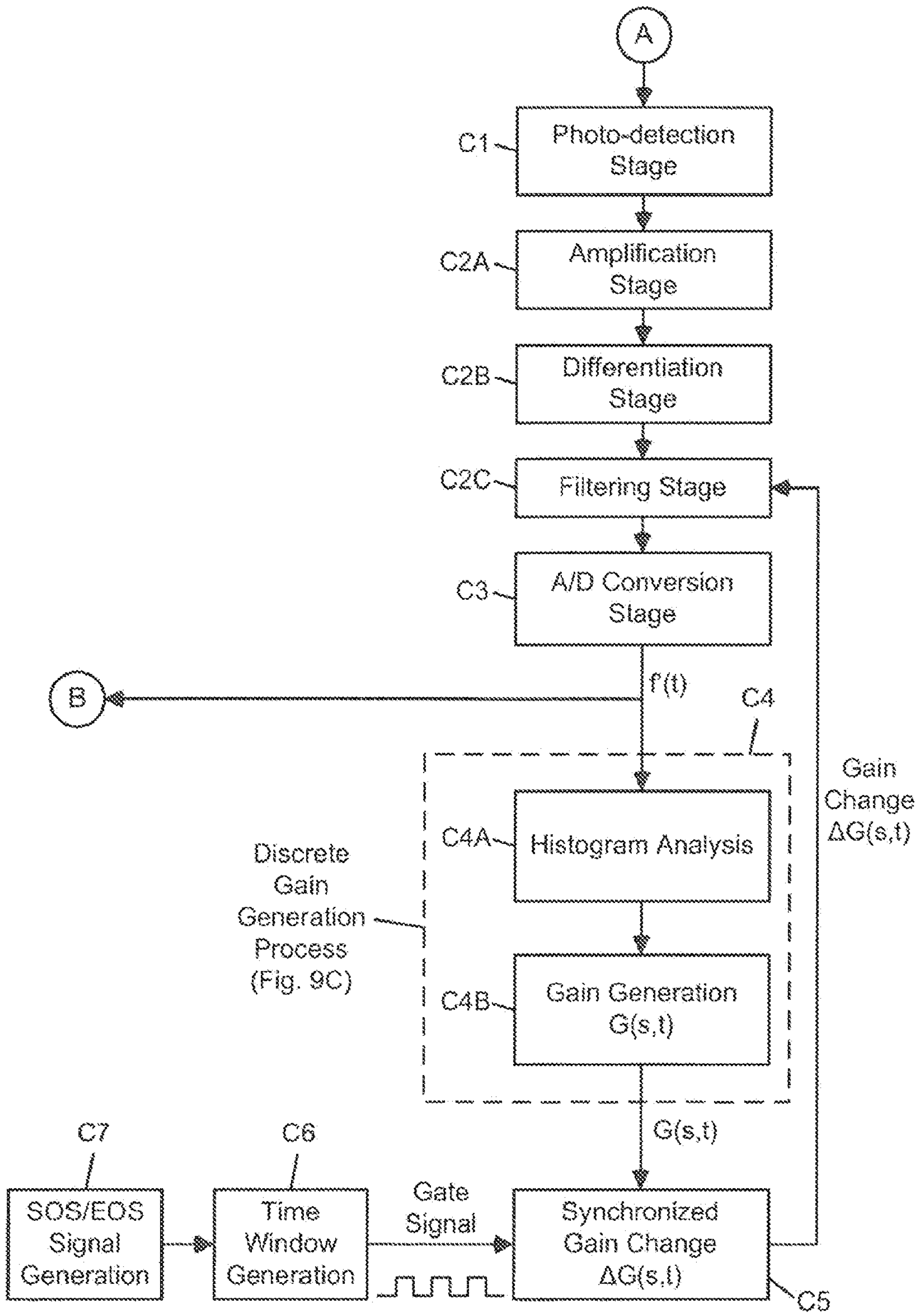
A
C1
Photo-detection Stage
C2A
Amplification Stage
C2B
Differentiation Stage
C2C
Filtering Stage
C3
A/D Conversion Stage
B
f'(t)
C4
Gain Change ΔG(s,t)
Discrete Gain Generation Process (Fig. 9C)
C4A
Histogram Analysis
C4B
Gain Generation G(s,t)
G(s,t)
C7
C6
SOS/EOS Signal Generation
Time Window Generation
Gate Signal
Synchronized Gain Change ΔG(s,t)
C5

FIG. 9B

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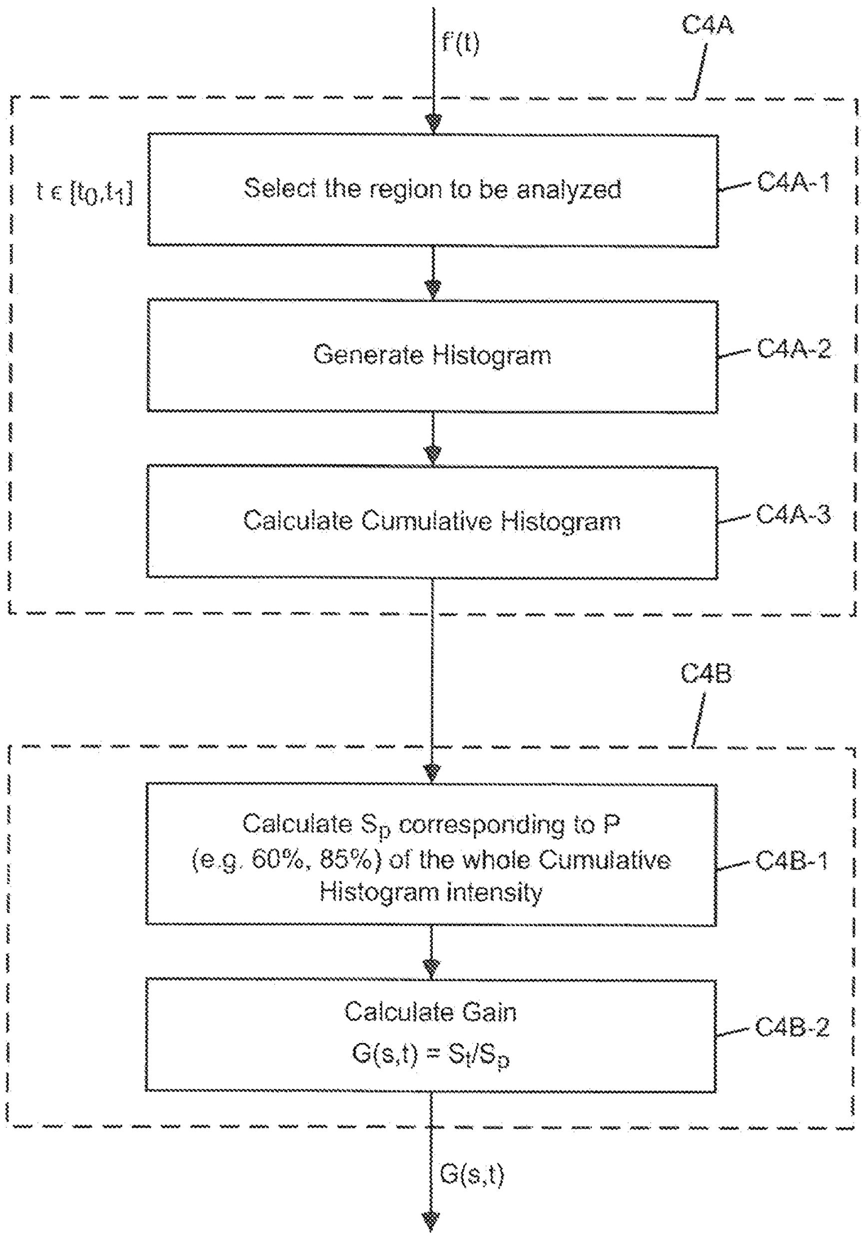

f'(t)
C4A
$t \in [t_0,t_1]$
Select the region to be analyzed
C4A-1
Generate Histogram
C4A-2
Calculate Cumulative Histogram
C4A-3
C4B
Calculate S_p corresponding to P (e.g. 60%, 85%) of the whole Cumulative Histogram intensity
C4B-1
Calculate Gain $G(s,t) = S_t/S_p$
C4B-2
G(s,t)

FIG. 9C

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INDICIA READING SYSTEM EMPLOYING DIGITAL GAIN CONTROL

CROSS-REFERENCE TO PRIORITY APPLICATION

The present application claims the benefit of U.S. Patent Application No. 61/632,423 for a Laser Scanning Code Symbol Reading System Employing Synchronized Digital Gain Control (SDGC), filed May 7, 2012, which is hereby incorporated by reference in its entirety.

BACKGROUND OF DISCLOSURE

1. Field of Disclosure

The present disclosure relates generally to improvements in reading code symbols on objects located anywhere over a large scanning range (e.g. 3 inches to over 30 feet from scanning window), and more particularly, to an improved method of and apparatus for processing analog scan data signals received during the laser scanning of objects located over large scanning distances.

2. Brief Description of the State of Knowledge in the Art

It is well known to scan bar code symbols on objects for purposes of automatically identifying the objects in diverse fields of use. Currently, several basic optical methods have been developed over the past three or more decades.

According to one method, bar code symbols are read by scanning a laser beam across the bar code symbol, and collecting and processing light from the return laser beam to extract information modulated onto the scanned beam by the light reflective characteristics of the bar code structure.

According to a second method, bar code symbols are read by capturing and buffering a digital image of a bar code symbol, and processing the digital image to recognize the bar code structure.

When using either method described above, the further that the object bearing the bar code symbol resides from a laser scanner, the weaker the return laser light signal will be at the time of signal detection at the photo-detector. Likewise, the further that the object bearing the bar code symbol resides from a digital imager, the weaker digital image intensity will be at the time of image detection. For laser scanners having a substantially large scanning, or working range, in particular, this potentially dramatic variation in signal intensity strength at the photo-detector places great demands on the electronic signal processing circuitry, and its ability to deliver sufficient signal-to-noise-ratio (SNR) performance over broad dynamic ranges of input signal operation.

Consequently, great efforts have been made over the past few decades to provide laser scanning type bar code scanners, in particular, with automatic gain control (AGC) capabilities that aim to control the gain of the various analog scan data signal processing stages, regardless of the input laser return signal strength. The following U.S. Patents describe prior art efforts to date to provide automatic gain control (AGC) capabilities in laser scanning bar code symbol readers: U.S. Pat. Nos. 7,822,349; 7,172,125; 6,827,272; 6,073,848; 5,914,478; 5,701;003; 5,612,259; 5,288,983; 5,168,148; 5,148,008; 4,843,222; and 4,792,666, incorporated herein by reference as set forth herein.

In general, a feedback control is implemented in the analog domain, and the gain of an amplified stage is adjusted according to a controller. The controller could be, but is not limited to, proportional control, PID control or fuzzy logic control, etc. Also, the amplifier refers to, but is not limited to preamplifier or gain stages along the signal path.

When performing middle and long range laser scanning, variable gains along the signal processing chain are desired to improve signal quality. Such multi-stage gain control is extremely important when a barcode target is located in the far field, which could be at least 30 feet away from the laser scanner.

During laser scanning bar code symbols, it is preferred that the gain is maintained substantially constant during each scan line sweep so that signal linearity is maintained, which is important for the barcode decoding. However, the AGC circuitry must have a fast response time once the object scanning distance, and/or other parameters, are changed. Thus, automatic gain control (AGC) suffers from a dilemma: how to maintain fast response time without sacrificing signal linearity during each scanning cycle.

Conventional analog AGC circuits have to change the gain continuously which limits the response time for automatic gain control. Moreover, the requirement of linearity during scan line generation further limits the usage of conventional AGC techniques in many applications. Also, it is known that digital AGC circuits can respond quickly between gain changes which gain adjustment significantly faster than analog-based AGC circuits.

However, despite the many improvements in AGC methods in laser scanning bar code symbol readers over the years, there is still a great need in the art for improved laser scanning bar code symbol reading system which exhibits fast response time and signal linearity, while avoiding the shortcomings and drawbacks of prior art systems and methodologies.

OBJECTS AND SUMMARY

Accordingly, a primary object of the present disclosure is to provide improved laser scanning bar code symbol reading system for use in diverse environments, which is free of the shortcomings and drawbacks of prior art systems and methodologies.

Another object is to provide a laser scanning bar code symbol reading system, wherein a synchronized digital gain control (SDGC) module is provided for controlling the gain of analog signal processing circuitry in a new way which improves response time without sacrificing signal linearity characteristics of the system.

Another object is to provide a laser scanning bar code symbol reading system, wherein the synchronized digital gain control (SDGC) module is synchronized using the start of scan (SOS) signals generated each time the laser scanning assembly undergoes a complete scanning cycle, and discrete gain changes are generated and provided to the gain stage only at a certain windows along the time domain.

Another object is to provide a laser scanning bar code symbol reading system, wherein the synchronized digital gain control (SDGC) module can be used to implement gain adjustments at one or more points along the analog scan data signal path such as, but not limited to, preamplifier stages, derivative stages, and filtering stages.

Another object is to provide a laser scanning code symbol reading system within an analog scan data signal processor, wherein a synchronized digital gain control module automatically controls the gain of at least one signal processing stage within the analog scan data signal processor, during each laser beam scanning cycle, in time synchronous manner using (i) start of scan (SOS) signals generated by a SOS detector and (ii) digitized data signals generated by the analog scan data signal processor.

Another object is to provide a laser scanning code symbol reading system having an analog scan data signal processor

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for producing digitized data signals, wherein during each laser beam scanning cycle, a synchronized digital gain control module processes the digitized data signals in response to start of scan (SOS) signals and generates digital control data that is transmitted to the analog scan data signal processor for controlling the gain of a signal processing stage therein during a corresponding laser beam scanning cycle.

Another object is to provide a method of controlling the gain of a signal processing stage within the analog scan data signal processor of a laser scanning code symbol reading system employing a laser scanning module, a start of scan (SOS) detector, and a synchronized digital gain control module.

Another object is to provide a method of controlling the gain of a signal processing stage within a laser scanning code symbol reading system, wherein a synchronized digital gain control module uses SOS signals to determine when to sample and process digitized data signals, and generate digital control data for use by at least one signal processing stage to control the gain of thereof during a corresponding laser beam scanning cycle.

Another object is to provide a method of controlling the gain of a signal processing stage within a laser scanning code symbol reading system, wherein digital gain control data is automatically produced during each laser beam scanning cycle, by a process comprising: (i) calculating a histogram from the digitized data signal sampled over a time interval determined using start of scan (SOS) signals; (ii) calculating a cumulative histogram from the calculated histogram; (iii) calculating the discrete gain value for the current laser beam scanning cycle, using the cumulative histogram; and (iv) calculating a discrete gain change value from the discrete gain value, and using the discrete gain change value, as well as digital control data, to control the gain of the at least one signal processing stage.

Another object is to provide such a method of controlling the gain of a signal processing stage within a laser scanning code symbol reading system, wherein the digital data signal can be either a digital representation of (i) the raw analog scan data signal intensity, or (ii) first derivative of the analog scan data signal, produced by the photo-collection and photo-detection module of the system during laser scanning operations.

These and other objects will become apparent hereinafter and in the Claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to more fully understand the Objects, the following Detailed Description of the Illustrative Embodiments should be read in conjunction with the accompanying Drawings, wherein:

FIG. **1** is a perspective view of an illustrative embodiment of a hand-supportable laser scanning bar code symbol reading system of the present disclosure, having the capacity to read bar code symbols over a large working range where the intensity of return laser signals will vary drastically due to distance-related attenuation factors;

FIG. **2** is a schematic block diagram of the system shown in FIG. **1**, describing the major system components of the laser scanning bar code symbol reading system illustrated in FIG. **1**, including the synchronized digital gain control (SDGC) module of the present disclosure;

FIG. **3**A is a schematic block diagram describing the major system components of the laser scanning bar code symbol reading system illustrated in FIG. **1**, showing the primary stages of a first illustrative embodiment of the synchronized digital gain control (SDGC) subsystem and process of the present disclosure, including (i) a light collection and photo-detector module with a photo-detection stage and a digitally-controlled pre-amplification stage with amplification controlled by its gain setting, and (ii) an analog scan data processing/digitizer module having an A/D signal conversion stage;

FIGS. **3**B through **3**D, when taken together, illustrate how the SDGC module controls the gain of a signal amplification stage processing a raw analog scan data signal, over three consecutive time windows (i.e. laser beam scanning cycles);

FIG. **4**A is a flow chart describing the primary steps carried out in the laser scanning bar code symbol reading system of FIG. **3**A, wherein upon detecting a trigger event in the system, the bar code symbol is automatically laser scanned, and scan data is captured and processed to automatically control the gain of the first amplifier stage in a synchronized manner, and any bar code symbol represented by collected digitized scan data is decoded (i.e. read) during the laser beam scanning cycle;

FIG. **4**B is a flow chart describing the steps carried out during the synchronized digital gain control (SDGC) process of FIG. **3**, where the analog scan data signal (i.e. analog barcode pattern signal) is processed, during a synchronized time window (i.e. between generation of the SOS and EOS signals during each scanning cycle);

FIG. **4**C is a flow chart describing a preferred method of processing the digitized scan data signal within the decode processor of FIG. **3**, involving histogram analysis and gain calculation;

FIG. **5**A is a schematic representation of a cumulative histogram of sampled signal strength values within the digital scan data signal;

FIG. **5**B is a schematic representation generated from a corresponding cumulative histogram, plotting frequency versus current signal level within the digital scan data signal;

FIG. **6**A is a schematic block diagram describing the major system components of the laser scanning bar code symbol reading system illustrated in FIG. **1**, showing the primary stages of a second illustrative embodiment of the synchronized digital gain control (SDGC) subsystem and process of the present disclosure, including (i) a light collection and photo-detection module having a photo-detection stage and a pre-amplification stage, and (ii) an analog scan data processing/digitizer module having a differentiation stage with digitally-controlled pre-amplification controlled by its gain setting, and an A/D signal conversion stage;

FIGS. **6**B through **6**D, when taken together, illustrate how the SDGC module controls the gain of a derivative processing stage with amplification, processing (the first or second) derivative of the analog scan data signal, over three consecutive time windows (i.e. laser beam scanning cycles);

FIG. **7**A is a flow chart describing the primary steps carried out in the laser scanning bar code symbol reading system of FIG. **6**, wherein upon detecting a trigger event in the system, the bar code symbol is automatically laser scanned, scan data captured and processed to automatically control the gain of the first amplifier stage in a synchronized manner, and any bar code symbol represented by collected digitized scan data decoded (i.e. read) during a given scanning cycle;

FIG. **7**B is a flow chart describing the steps carried out during the synchronized digital gain control (SDGC) process illustrated in FIG. **6**, where the analog scan data signal (i.e. analog barcode pattern signal) is processed, during a synchronized time window defined by the generation of start of scan (SOS) signals during each laser beam scanning cycle;

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FIG. **7**C is a flow chart describing a preferred method of processing the digitized scan data signal within the programmed decode processor shown in FIG. **6**, involving histogram analysis and gain calculation;

FIG. **8**A is a schematic block diagram describing the major system components of the laser scanning bar code symbol reading system illustrated in FIG. **1**, showing the primary stages of a third illustrative embodiment of the synchronized digital gain control (SDGC) subsystem and process of the present disclosure, including (i) a light collection and photo-detection module having a photo-detection stage and a pre-amplification stage, and (ii) an analog scan data processing/digitizer module having a differentiation stage, a filtering stage with digitally-controlled amplification controlled by its gain setting, and an A/D signal conversion stage;

FIGS. **8**B through **8**D, when taken together, illustrate how the SDGC module controls the gain of a signal filtering stage with amplification, processing a filtered (first or second) derivative of the analog scan data signal, over three consecutive time windows (i.e. laser beam scanning cycles);

FIG. **9**A is a flow chart describing the primary steps carried out in the laser scanning bar code symbol reading system of FIG. **8**, wherein upon detecting a trigger event in the system, the bar code symbol is automatically laser scanned, scan data captured and processed to automatically control the gain of the first amplifier stage in a synchronized manner, and any bar code symbol represented by collected digitized scan data decoded (i.e. read) during a given scanning cycle;

FIG. **9**B is a flow chart describing the steps carried out during the synchronized digital gain control (SDGC) process illustrated in FIG. **8**, where the analog scan data signal (i.e. analog barcode pattern signal) is processed, during a synchronized time window defined by the generation of start of scan (SOS) signals during each scanning cycle; and

FIG. **9**C is a flow chart describing a preferred method of processing the digitized scan data signal within the programmed decode processor of FIG. **8**, involving histogram analysis and gain calculation.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

Referring to the figures in the accompanying Drawings, the illustrative embodiments of the dual laser-scanning bar code symbol reading system and will be described in great detail, wherein like elements will be indicated using like reference numerals

Overview of the Laser Scanning Bar Code Symbol Reading System Employing Synchronized Digital Gain Control

Referring now to FIGS. **1** through **2**, the hand-supportable laser scanning bar code symbol reading system **1** will be described in detail.

As shown in FIGS. **1** and **2**, the hand-supportable laser scanning bar code symbol reading system **100** is shown comprising the following components: a hand-supportable housing **102** having a head portion and a handle portion supporting the head portion; a light transmission window **103** integrated with the head portion of the housing **102**; a 2-position manually-actuated trigger switch **104** integrated with the handle portion of the housing **102**, for sending trigger signals to controller **150** and activating the laser pointing/aiming subsystem **219** and the laser scanning module **105**; a laser scanning module **105**, for repeatedly scanning, across the laser scanning field, a visible laser beam generated by a laser source **112** (e.g. VLD or IR LD) having optics to produce a laser scanning beam focused in the laser scanning field, in response to a control signal generated by a system controller **150**; wherein the laser scanning module **105** also includes a laser drive circuit **151** for receiving control signals from system controller **150**, and in response thereto, generating and delivering laser (diode) drive current signal to the laser source **112** to produce a laser scanning beam during the method of bar code symbol reading described in FIG. **4**; a start of scan/end of scan (SOS/EOS) detector **127** for generating SOS timing signals indicating the start of each laser beam sweep (i.e. scanning cycle), and EOS timing signals indicating the end of each laser beam sweep, and sending these SOS/EOS timing signals to the system controller **150**, as well as decode processor **108** and SDGC module **109**; a set of scan line data line buffers **160** for buffering each complete line of scan data collected during a complete sweep of the laser scanning beam across the laser scanning field during each scanning cycle (i.e. one buffer for each scanning directions); a photo (i.e. light) collection and photo-detection module **106**, including (i) light collection optics for collecting light reflected/scattered from a scanned object in the scanning field, and (ii) a photo-detector for detecting the intensity of collected light and generating an analog scan data signal corresponding to said detected light intensity during scanning operations; an analog scan data signal processor/digitizer **107** for processing the analog scan data signals and converting the processed analog scan data signals into digital scan data signals, which are then converted into digital words representative of the relative width of the bars and spaces in the scanned code symbol structure; a scan data signal intensity detection module **143**, preferably implemented within scan data processor/digitizer **107**, for continuously (i) processing the return analog (or digital) scan data signals, (ii) detecting and analyzing the intensity (i.e. magnitude) of the laser return signal, (iii) determining (e.g. estimating) the range or distance of the scanned object, relative to the scanning window, and then (iv) transmitting the range indication (i.e. estimation) signal (e.g. in the form of a digital data value) to the decode processor **108** so that it can program or set an appropriate laser beam sweep angle $\alpha(t)$, as required in any given application; programmed decode processor **108** for decode processing digitized data signals, and generating symbol character data representative of each bar code symbol scanned by the laser scanning beam; a synchronized digital gain control (SDGC) module **109**, interfaced with the analog scan data processor/digitizer (ASIC chip) **107** and light collection and photo-detection module **106**, for controlling the gain of at least one stage within the analog scan data signal processor/digitizer **107** and/or the light collection and photo-detection module **106**, on a real-time, scanning-cycle basis; an input/output (I/O) communication interface module **109** for interfacing with a host communication system and transmitting symbol character data thereto via wired or wireless communication links that are supported by the symbol reader and host system; and a system controller **150** for generating the necessary control data signals for controlling operations within the hand-supportable laser scanning bar code symbol reading system.

As shown in FIG. **2**, the laser scanning module **105** comprises a number of subcomponents, namely: laser scanning assembly **110** with an electromagnetic coil **128** and rotatable scanning element **134** supporting a polygon mirror **134**A, or an oscillating (or flipper) type laser scanning mechanism **134** supporting a planar mirror element **134**A; a coil drive circuit **111** for generating an electrical drive signal to drive the electromagnetic coil **128** in the laser scanning assembly **110**; and a laser beam source **112** for producing a visible laser beam **113**A; and a beam deflecting mirror **114** for deflecting the laser beam **113**A as incident beam **113**B towards the mirror component of the laser scanning assembly **110**, which sweeps

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the deflected laser beam **113**C across the laser scanning field and a bar code symbol **16** that might be simultaneously present therein during system operation.

As shown in FIG. **2**, the laser scanning module **105** is typically mounted on an optical bench, printed circuit (PC) board or other surface where the laser scanning assembly is also, and includes a coil support portion **110** for supporting the electromagnetic coil **128** (in the vicinity of the permanent magnet **135**) and which is driven by a drive circuit **111** so that it generates magnetic forces on opposite poles of the permanent magnet **135**, during scanning assembly operation.

Specification of the First Illustrative Embodiment of the Synchronized Digital Gain Control (SDGC) Process of the Present Disclosure

FIG. **3**A describes a first illustrative embodiment of a synchronized digital gain control (SDGC) subsystem and process supported in the laser scanning bar code symbol reading system of FIG. **1**. As shown, the decode processor **108** and SDGC module **109** are realized by a programmed microprocessor and associated memory architecture, and both modules receive SOS and EOS timing signals from the SOS/EOS detector **127** which can be realized using Hall-effect sensor and one or more permanent magnets embedded in the scanner rotor, or other techniques well known in the art.

As shown in FIG. **3**A, the photo-collection and photo-detection module **106** includes at least a photo-detection stage **106**A and a digitally-controlled pre-amplification stage **106**B. The digitally-controlled pre-amplification stage **106**B receives a discrete gain change signal (i.e. digital control data) ΔG(S, t) from the microprocessor-implemented SDGC module **109**. The rate at which the module **106** receives discrete gain control updates depends on the frequency of the laser scanning mechanism (e.g. flipper mechanism, rotating polygon, etc), which is effectively measured by start of scan (SOS) signals generated by the SOS/EOS detector **12**. As shown in the first illustrative embodiment of FIG. **3**B, the SDGC module **109** updates the gain of the amplification stage **106**B of light collection and photo-detection module **106** once every laser beam scanning cycle, using the synchronized digital gain control (SDGC) process depicted in FIGS. **4**B and **4**C. Notably, the SDGC process is called during the main control process shown in FIG. **4**A, carried out in the laser scanning bar code symbol reading system **1** shown in FIG. **1**, to be described herein below.

In response to a triggering event (i.e. manually pulling trigger **104** to its first position), the system controller **150** enables subsystem **219** to generate and project a cone-like visible aiming beam **221** within the laser scanning field **115** of the system. After the aiming beam **221** is aligned with the bar code symbol to be scanned, the user pulls the trigger switch **104** to its second position. In response, the system controller **150** enables the laser scanning module **105** to generate and project a laser scanning beam through the light transmission window **103**, and across the laser scanning field external to the hand-supportable housing, for scanning an object in the scanning field. The laser scanning beam is generated by laser beam source **112** in response to control signals generated by the system controller **150**. The scanning element (i.e. mechanism) **134** begins to repeatedly scan the selected laser beam across a code symbol residing on an object in the laser scanning field **115**. Then, the light collection optics **106** collects light reflected/scattered from scanned code symbols on the object in the scanning field, and the photo-detector (in the photo-detection stage **106**A) automatically detects the intensity of collected light (i.e. photonic energy) and generates an analog scan data signal (i.e. bar code pattern signal) corresponding to the light intensity detected during scanning operations. The analog scan data signal processor/digitizer module **107** processes the analog scan data signals, and the A/D conversion stage **107**B converts the processed analog scan data signals into digitized data signals including the digital raw intensity data signal f(t) corresponding to the intensity of raw (i.e. unfiltered) analog scan data signal, and also the digital first derivative data signal f'(t) during processing at a differentiation stage (not shown) within processor/digitizer module **107**. While both the digital raw intensity data signal f(t) and the digital first derivative data signal f'(t) are typically transmitted to the programmed decode processor **108** for use during decode processing, only the digital raw intensity data signal f(t) is transmitted to the SDGC module **109** for processing in this illustrative embodiment. However, in other illustrative embodiments, both the digital raw intensity data signal f(t) and the digital first derivative data signal f'(t) can be transmitted to the SDGC module **109** for use in generating gain control data signals.

The SOS/EOS detector **127** generates a SOS signal upon detecting the start of the first and each subsequent laser beam scanning cycle, and these SOS signals are transmitted to the SDGC module **109** and the programmed decode processor **108**. The SDGC module **109** uses the SOS signal from detector **127** and raw digital intensity data signal f(t) from the scan data signal processor/digitizer module **107** to generate digital control data signals for transmission to the digitally-controlled analog signal amplification stage **106**B within the light collection and photo-detection module **106**, to control the gain thereof, during a corresponding scanning cycle, in accordance with the principles of the present disclosure, to be described in greater detail herein. This process is repeated each cycle to control the gain of the amplification stage in module **6**. Also, the programmed decode processor **108** decode processes digitized data signals, and generates symbol character data representative of each bar code symbol scanned by the laser scanning beam. Symbol character data corresponding to the bar codes read by the decoder **108** is then transmitted to the host system via the I/O communication interface **140** which may support either a wired and/or wireless communication link, well known in the art. During laser scanning operations, the system controller **150** automatically generates the necessary control signals for controlling operations within the hand-supportable laser scanning bar code symbol reading system.

Referring to FIG. **4**A, a method will now be described for reading bar code symbols using the laser scanning bar code reader **100**, described above, wherein the gain of the analog scan data signal processing stage in module **106**, is automatically controlled in a synchronized manner, as the analog scan data signal is collected and processed, and digitized data signals are generated and processed by the SDGC module **109** during each laser beam scanning cycle.

As indicated in FIG. **4**A, the process orchestrated by system controller **150** begins at the START Block. Then at Block A, the system controller **150** determines if a trigger event has occurred (i.e. whether or not trigger **104** has been manually depressed by the operator upon seeing an object in the laser scanning field and pointing the head portion of the housing towards the object). When the trigger event is detected at Block A, the system controller **150** enables, at Block B, the laser scanning module **105** (including the laser VLD **112**, scanning mechanism and associated electronics and photo-electronics) to scan the object with a laser scanning beam generated by the VLD **112**, and collect and buffer a pair of lines of scan data in buffers **160**, representative of collected scan data from the laser scanned object during both laser scanning directions.

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As shown in FIG. **4**A, at Block C, the SDGC process of the present disclosure is carried out in an automatic manner, during each laser scanning cycle, to control the gain of the amplification stage of the light collection and detection module **106**, at the beginning of each laser scanning cycle, and this value is stored and used only for this laser scanning cycle, and will be updated during the beginning of the next scanning cycle, as described in detail below with reference to FIGS. **4**A through **5**B.

As indicated at Block D in FIG. **4**A, the decode processor **108** runs a decode algorithm on the captured lines of scan data buffered in the scan line data buffer **160**. If at Block E, a bar code symbol is decoded, then at Block F, the produced symbol character data is transmitted to the host system, and the system controller returns to Block A.

If, however, at Block E in FIG. **4**A a bar code symbol is not decoded, then the system controller **150** determines at Block G whether or not the maximum scan attempt threshold has been reached, and if not, then the system controller **150** returns to Block B, and resumes the flow as indicated. However, if at Block G, the system controller **150** determines that the maximum scan attempt threshold has been accomplished, then the system controller **150** proceeds to Block H and sends a Failure to Decode notification to the operator, and returns to Block A, as shown.

Specification of Synchronized Digital Gain Control Process of the First Illustrative Embodiment

FIG. **4**B describes the steps carried out during the synchronized digital gain control (SDGC) process of FIG. **3**, which is automatically and transparently called at Block C in the system control process described in FIG. **4**A, at the beginning of each scanning cycle.

As indicated at Block C**1** in FIG. **4**B, the first step of the SDGC process begins at photo-detection stage (i.e. photo-detector) where collected return laser light is detected by the photo-detector and a corresponding analog scan data signal or analog barcode pattern signal is generated.

As indicated at Block C**2** in FIG. **4**B, the amplification stage amplifies the analog scan data signal, by the gain value determined by the SDGC module **109** during each scanning cycle.

As indicated at Block C**3** in FIG. **4**B, the A/D conversion stage **107**B converts the amplified analog scan data signal, including the first derivative signal, into corresponding digital scan data signals, including the digital raw intensity data signal f(t) and the digital first derivative data signal f'(f), providing indications of the strength or magnitude in signal level transitions and other signal characteristics that might be useful during decode processing, as well as during the synchronized digital gain control process.

As indicated a Block C**4** in FIG. **4**B, a discrete gain calculation/estimation process is carried out at the beginning (i.e. start) of each scanning cycle (i.e. in response to detection of the SOS signal) using a two-step method, namely: performing a histogram analysis on the time-sampled digital intensity data signal f(t) indicated at Block C**4**A; and generating a discrete gain value G(s,t) for the amplification stage of the photo-collection and detection module **6**, as indicated at Block C**4**B. In general, the discrete gain signal G(s, t) is a function of the signal strength (e.g. intensity or amplitude), and timing window, t. The signal strength could be, but is not limited to, the first derivative signal, raw digital scan data signal, etc. The timing window t is generated by the SOS/EOS detector which can be implemented in different ways depending on the type of laser scanning system used. This ensures that gain change occurs only during the synchronized time window (i.e. when the gate timing signal does to a logical high value) so that the signal has constant gain during each scanning cycle (i.e. laser beam sweep).

In FIG. **4**C, the digital gain calculation/estimation process of the preferred embodiment is described in greater detail. As shown, this process comprises the following steps: at Block C4A-**1**, selecting a time region over which the sampled digital raw intensity data signal f(t) is to be analyzed (e.g. from t_1 to t_0); at Block C**4**A-**2**, generate a histogram based on the region of the sampled digital raw scan data intensity signal f(t) selected in Block C**4**A-**1**; at Block C**4**A-**3**, calculating a cumulative histogram based on the histogram generated in Block C**4**A-**2**; at Block C**4**B-**1**, calculating the current signal level S(p) corresponding to the frequency of the signal level, p, observed over the selected time region (e.g. 60% or 85% of the whole intensity value); and at Block C**4**B-**2**, calculating the discrete gain value G(s,t), for the current scanning cycle, using the following formula: $G(s,t)=S_t/S_p$ where S_t is the target signal level, and S_p is the current signal level corresponding to P (e.g. 60% or 85%) of the whole cumulative histogram. This process will be described in greater technical detail below with reference to FIGS. **5**A and **5**B.

As indicated at Block C**4**A-**1** in FIG. **4**C, a given digital raw intensity data signal f(t) is sampled over a selected time region, extending from a start point a time t**1**, to an end point at time t**2**. The sampled digital raw intensity data signal f(t) is buffered within the SDGC module for subsequent processing. The system can be configured so that the selected time region occurs over a certain area/region of the scan line (e.g. the left side of the scan line, the right side of the scan line, or in the center region of the scan line).

As indicated at Block C**4**A-**2** in FIG. **4**C, a histogram is calculated for the sampling scanning cycle, by classifying each sample point in the sampled digital raw intensity data signal f(t), into one or M possible bins (i.e. storage locations), where each bin represents a particular signal level or range of signal level of the digital raw intensity data signal f'(t), as illustrated in FIG. **5**A. For the time interval [t**1**, t**2**], the frequency of the signal level associated with each bin is calculated to provide the histogram shown in FIG. **5**A. Notably, this histogram analysis removes the effects of strong return laser signals having great differences in signal intensity, produced when laser scanning targets with surface areas (i) having specular-type reflection characteristics, and/or (ii) located at different distances from the laser scanner, etc.

As indicated at Block C**4**A-**3** in FIG. **4**C, a cumulative histogram is calculated using the corresponding histogram by counting the cumulative number of observed signal levels (i.e. observations on f(t)) in all of the bins up to the specified bin, as illustrated in FIG. **5**B.

As indicated at Block C**4**B-**1** in FIG. **4**C, the current signal level S_p (or S(p)) corresponding to a percentage p (e.g. 60% or 85%) of the whole cumulative histogram, observed over the selected time region, is calculated, as illustrated in FIG. **5**B.

Then, as indicated at Block C**4**B-**2** in FIG. **4**C, a discrete gain value G(s,t) is calculated for the current scanning cycle, using the following formula: $G(s,t)=S_t/S_p$ where S_t is the target signal level, and S_p is the current signal level corresponding to a percentage P (e.g. 60% or 85%) of the whole cumulative histogram.

In general, the target signal level S_t is the signal level at which system performance is optimized, and is set prior to system operation. Typically, this value is determined from experimentation, and while it will be dependent upon the stage at which SDGC is applied, this target value should remain constant during a long period of operation of the system. Such experimentation will typically take place during system design, but may be carried out during a diagnostic

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procedure during which S_r is determined experimentally, and then programmed into the SDGC module prior to system operation. Notably, the units of measure of S_r will depend on the signal processing stage where SDGC is applied. However, regardless of whether SGDC is applied to the preamplifier stage in the photo-collection and detection module, or derivative or other amplification stages in the analog signal processing/digitizing module, the S_r value typically will be chosen as a percentage of the maximum possible signal swing that such signal amplification/gain circuitry can operate, without going into a state of saturation or otherwise generating undesired non-linear signal distortion due to excessive swings in voltages that maintain the operation of the amplification circuitry.

As indicated in the SDGC process of FIG. **4**B, the discrete gain value G(s, t) calculated in Block C**4** is provided to Block C**5**, where a synchronized gain change value ΔG(s, t) is computed, for the current time window (i.e. laser beam scanning cycle), determined by time window block C**6**, driven by SOS/EOS signal generation block C**7**, as described above. The synchronized discrete gain change value ΔG(s,t) (i.e. a digital numerical value) is then transmitted to the digitally-controlled analog amplification stage at Block C**2**, to instantly change the gain of this stage to a new gain value determined by the synchronized discrete gain change value ΔG(s,t). Thus, by selecting the target signal level S_r at an optimum value of system operation, the SDGC module automatically computes and applies the synchronized discrete gain change value ΔG(s, t), during each scanning cycle (i.e. time window) so that the output signal level from the digitally-controlled analog amplification stage closely approaches the target signal level S_r and system performance is optimized.

Having described the operation of the SDGC process during each scanning cycle, it now will be helpful to refer to FIGS. **3**B through **3**D and describe how an analog scan data signal is processed by a stage of signal processing circuitry having its gain controlled by the SDGC module **109** over three consecutive time windows (i.e. scanning cycles).

As shown in FIGS. **3**B, **3**C and **3**D, during the first (initial) scanning cycle, scan line N−1 is generated and associated scan data collected. As shown, the SOS signal is logically low, the gain is maintained at a first constant level, and the scan data signal f(t) (or f'(t)) is amplified by the first gain level.

During the second scanning cycle, scan line N is generated and associated scan data collected. As shown, the SOS signal transitions from a logically low to logically high value (indicating a new scanning cycle), the gain is increased at a second constant level, and the scan data signal f(t) (or f'(t)) is amplified by the second gain level.

Then, during the third scanning cycle, scan line N+1 is generated and associated scan data collected. As shown, the SOS signal transitions from a logically low to logically high value (indicating a new scanning cycle), the gain is maintained constant at the second gain level, and the scan data signal f(t) (or f'(t)) is amplified by the same second gain level.

Thereafter, the SDGC process repeats itself automatically, each and every scanning cycle, in a manner transparent to the system user, to maintain the intensity of processed analog scan data signals relatively constant before conversion into corresponding digital data signals.

Specification of the Second Illustrative Embodiment of the Synchronized Digital Gain Control (SDGC) Process of the Present Disclosure

FIG. **6**A describes a second illustrative embodiment of a synchronized digital gain control (SDGC) subsystem and process supported in the laser scanning bar code symbol reading system of FIG. **1**. As shown, the decode processor **108** and SDGC module **109** are realized by a programmed microprocessor and associated memory architecture, and both modules receive SOS and EOS timing signals from the SOS/EOS detector **127** which can be realized using Hall-effect sensor and one or more permanent magnets embedded in the scanner rotor, or other techniques well known in the art.

As shown in FIG. **6**A, the photo-collection and photo-detection module **106** includes at least a photo-detection stage **106**A and an amplification stage **106**B. Also, the analog scan data signal processor/digitizer **107** includes a differentiation stage **107**A with digitally-controlled pre-amplification determined by its gain setting, and an A/D conversion stage **107**B for A/D signal conversion. As shown, the differentiation stage **107**A periodically receives a discrete gain change signal (i.e. digital control data) ΔG(S, t) from the microprocessor-implemented SDGC module **109**. The rate at which the module **107** receives discrete gain control updates ΔG(S, t) depends on the frequency of the laser scanning mechanism (e.g. flipper mechanism, rotating polygon, etc). The SDGC module **109** updates the gain of the differentiation stage once every laser beam scanning cycle, using the synchronized digital gain control (SDGC) process of FIGS. **7**B and **7**C, which is called during the main control process shown in FIG. **7**A, carried out in the laser scanning bar code symbol reading system **1** shown in FIG. **1**, to be described herein below.

In response to a triggering event (i.e. manually pulling trigger **104** to its first position), the system controller **150** enables subsystem **219** to generate and project a cone-like visible aiming beam **221** within the laser scanning field **115** of the system. After the aiming beam **221** is aligned with the bar code symbol to be scanned, the user pulls the trigger switch **104** to its second position. In response, the system controller **150** enables the laser scanning module **105** to generate and project a laser scanning beam through the light transmission window **103**, and across the laser scanning field external to the hand-supportable housing, for scanning an object in the scanning field. The laser scanning beam is generated by laser beam source **112** in response to control signals generated by the system controller **150**. The scanning element (i.e. mechanism) **134** begins to repeatedly scan the selected laser beam across a code symbol residing on an object in the laser scanning field **115**. Then, the light collection optics **106** collects light reflected/scattered from scanned code symbols on the object in the scanning field, and the photo-detector (**106**) automatically detects the intensity of collected light (i.e. photonic energy) and generates an analog scan data signal (i.e. bar code pattern signal) corresponding to the light intensity detected during scanning operations. The differentiation stage **107**A and filtering stage **107**C process the analog scan data signals, and the A/D conversion module **107**B converts the processed analog scan data signals into digitized data signals, including digital raw intensity signal f(t) and the first digital derivative data signal f'(t). While both the digital raw intensity signal f(t) and the derivative first derivative signal f'(t) are typically transmitted to the programmed decode processor **108** for use during decode processing, only the digital first derivative data signal f'(t) is transmitted to the SDGC module **109** in this illustrative embodiment. In other illustrative embodiments, whereas, both the digital raw intensity signal f(t) and the digital first derivative data signal f'(t) can be transmitted to the SDGC module **109** for use in generating gain control data signals.

The SOS/EOS detector **127** generates a SOS signal upon detecting the start of the first and each subsequent laser beam scanning cycle, and these SOS signals are transmitted to the SDGC module **109** and the programmed decode processor **108**. The SDGC module **109** uses the SOS signal from detector **127** and the digital derivative data signal f'(t) from pro-

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cessor/digitizer **107** to generate digital control data signals for transmission to the digitally-controlled analog signal differentiation stage **107**A within the analog scan data signal processor/digitizer **107**, to control the gain thereof, during a corresponding scanning cycle, in accordance with the principles of the present disclosure, to be described in greater detail herein. This process is repeated each cycle to control the gain of the digitally-controlled differentiation stage **107**A in scan data signal processor/digitizer module **107**, during laser scanning operations. Also, the programmed decode processor **108** decode processes digitized data signals, and generates symbol character data representative of each bar code symbol scanned by the laser scanning beam. Symbol character data corresponding to the bar codes read by the decoder **108** is then transmitted to the host system via the I/O communication interface **140** which may support either a wired and/or wireless communication link, well known in the art. During laser scanning operations, the system controller **150** automatically generates the necessary control signals for controlling operations within the hand-supportable laser scanning bar code symbol reading system.

Referring to FIG. **7**A, a method will now be described for reading bar code symbols using the laser scanning bar code reader **100**, wherein the gain of the differentiation stage in the analog scan data signal processor/digitizer **107**, is automatically controlled in a synchronized manner, as the analog scan data signal is collected and processed, and digitized scan data is generated and processed by the SDGC module **109** during each laser beam scanning cycle.

As indicated in FIG. **7**A, the process orchestrated by system controller **150** begins at the START Block. Then at Block A, the system controller **150** determines if a trigger event has occurred (i.e. whether or not trigger **104** has been manually depressed by the operator upon seeing an object in the laser scanning field and pointing the head portion of the housing towards the object). When the trigger event is detected at Block A, the system controller **150** enables, at Block B, the laser scanning module **105** (including the laser VLD **112**, scanning mechanism and associated electronics and photo-electronics) to scan the object with a laser scanning beam generated by the VLD **112**, and collect and buffer a pair of lines of scan data in buffers **160**, representative of collected scan data from the laser scanned object during both laser scanning directions.

As shown in FIG. **7**A, at Block C, the SDGC process of the present disclosure is carried out in an automatic manner, during each laser scanning cycle, to control the gain of the signal differentiation stage **107**A of the analog scan data signal processor/digitizer module **107**, at the beginning of each laser scanning cycle, and this value is stored and used only for this laser scanning cycle, and will be updated during the beginning of the next scanning cycle, as will be described in detail below with reference to FIGS. **7**A.

As indicated at Block D in FIG. **4**A, the decode processor **108** runs a decode algorithm on the captured lines of scan data buffered in the scan line data buffer **160**. If at Block E, a bar code symbol is decoded, then at Block F, the produced symbol character data is transmitted to the host system, and the system controller returns to Block A.

If, however, at Block E in FIG. **7**A a bar code symbol is not decoded, then the system controller **150** determines at Block G whether or not the maximum scan attempt threshold has been reached, and if not, then the system controller **150** returns to Block B, and resumes the flow as indicated. However, if at Block G, the system controller **150** determines that the maximum scan attempt threshold has been accomplished, then the system controller **150** proceeds to Block H and sends a Failure to Decode notification to the operator, and returns to Block A, as shown.

Specification of Synchronized Digital Gain Control Process Carried Out In the Second Illustrative Embodiment

FIG. **7**B describes the steps carried out during the synchronized digital gain control (SDGC) process of FIG. **3**, which is automatically and transparently called at Block C in the system control process described in FIG. **7**A, at the beginning of each scanning cycle.

As indicated at Block C**1** in FIG. **7**B, the first step of the SDGC process begins at photo-detection stage (i.e. photo-detector) where collected return laser light is detected by the photo-detector and a corresponding analog scan data signal or analog barcode pattern signal is generated.

As indicated at Block C**2** in FIG. **7**B, the amplification stage amplifies the analog scan data signal, by the gain value determined by the SDGC module **109** during each scanning cycle.

As indicated at Block C**3** in FIG. **7**B, the A/D conversion stage **107**B converts the amplified analog scan data signal, including the first derivative signal, into corresponding digital scan data signals, including the digital raw intensity data signal f(t), and the digital first derivative data signal f'(t) providing indications of the strength or magnitude in signal level transitions and other signal characteristics that might be useful during decode processing, as well as during the synchronized digital gain control process.

As indicated a Block C**4** in FIG. **7**B, a discrete gain calculation/estimation process is carried out at the beginning (i.e. start) of each scanning cycle (i.e. in response to detection of the SOS signal) using a two-step method, namely: performing a histogram analysis on the time-sampled digital first derivative data signal f'(t) indicated at Block C**4**A; and generating a discrete gain value G(s,t) for the differentiation stage **107**A of the processor/digitizer module **107**, as indicated at Block C**4**B. In general, the discrete gain signal G(s, t) is a function of the signal strength (e.g. intensity or amplitude), and timing window, t. The signal strength could be provided by the digital first derivative signal f'(t) as in FIG. **6**A, the digital raw intensity data signal f(t) as in FIG. **3**A, or a combination thereof in an alternative embodiment. The timing window t is generated by the SOS/EOS detector which can be implemented in different ways depending on the type of laser scanning system used. This ensures that gain change occurs only during the synchronized time window (i.e. when the gate timing signal does to a logical high value) so that the signal has constant gain during each scanning cycle (i.e. laser beam sweep).

In FIG. **7**C, the digital gain calculation/estimation process of the preferred embodiment is described in greater detail, as comprising the following steps: at Block C**4**A-**1**, selecting a time region over which the sampled digital first derivative data signal f'(t) is to be analyzed (e.g. from t**1** to t**0**); at Block C**4**A-**2**, generate a histogram based on the region of the sampled digital first derivative data signal f'(t) selected in Block C**4**A-**1**; at Block C**4**A-**3**, calculating a cumulative histogram based on the histogram generated in Block C**4**A-**2**; at Block C**4**B-**1**, calculating the current signal level S(p) as p (e.g. 60% or 85%) of the whole cumulative histogram intensity value; and at Block C**4**B-**2**, calculating the discrete gain value G(s,t), for the current scanning cycle, using the following formula: $G(s,t)=S_t/S_p$ where S_t is the target signal level, and S_p is the current signal level corresponding to p (e.g. 60% or 85%) of the whole cumulative histogram intensity. This

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process has been described in great technical detail above with reference to FIGS. **5**A and **5**B, and will not be repeated to avoid redundancy.

As indicated in the SDGC process of FIG. **7**B, the discrete gain value G(s, t) calculated in Block C**4** is provided to Block C**5**, where a synchronized gain change value ΔG(s, t) is computed, for the current time window (i.e. laser beam scanning cycle), determined by time window block C**6**, driven by SOS/EOS signal generation block C**7**, as described above. The synchronized discrete gain change value ΔG(s,t) (i.e. a digital numerical value) is then transmitted to the digitally-controlled analog amplification stage at Block C**2**, to instantly change the gain of this stage to a new gain value determined by the synchronized discrete gain change value ΔG(s,t). Thus, by selecting the target signal level S_r at an optimum value of system operation, the SDGC module automatically computes and applies the synchronized discrete gain change value ΔG(s, t), during each scanning cycle (i.e. time window) so that the output signal level from the digitally-controlled analog amplification stage closely approaches the target signal level S_r and system performance is optimized.

The SDGC process describes above operates in a manner similar to that described in connection with the first illustrative embodiment, and illustrated in FIGS. **3**B through **3**D.

This SDGC process repeats itself automatically, each and every scanning cycle, in a manner transparent to the system user, to maintain the intensity of processed analog scan data signals relatively constant before conversion into corresponding digital data signals.

Specification of the Third Illustrative Embodiment of the Synchronized Digital Gain Control (SDGC) Process of the Present Disclosure

FIG. **8**A describes a third illustrative embodiment of a synchronized digital gain control (SDGC) subsystem and process supported in the laser scanning bar code symbol reading system of FIG. **1**. As shown, the programmed decode processor module **108** and SDGC module **109** are realized by a programmed microprocessor and associated memory architecture, and both modules receive SOS and EOS timing signals from the SOS/EOS detector **127** which can be realized using Hall-effect sensor and one or more permanent magnets embedded in the scanner rotor, or other techniques well known in the art.

As shown in FIG. **8**A, the photo-collection and photo-detection module **106** includes at least a photo-detection stage **106**A and an amplification stage **106**B. Also, the analog scan data signal processor/digitizer **107** includes a differentiation stage **107**A, a filtering stage **107**C with digitally-controlled pre-amplification characterized by its gain setting, and an A/D signal conversion stage **107**B. As shown, the filtering stage **107**C periodically receives a discrete gain change signal (i.e. digital control data) ΔG(S, t) from the microprocessor-implemented SDGC module **109**. The rate at which the module **107** receives discrete gain control ΔG(S, t) updates depends on the frequency of the laser scanning mechanism (e.g. flipper mechanism, rotating polygon, etc). The SDGC module **109** updates the gain of the differentiation stage once every laser beam scanning cycle, using the synchronized digital gain control (SDGC) process of FIGS. **9**B and **9**C. The SDGC process is called during the main control process shown in FIG. **9**A, which is carried out in the laser scanning bar code symbol reading system **1** shown in FIG. **1**, to be described herein below.

In response to a triggering event (i.e. manually pulling trigger **104** to its first position), the system controller **150** enables subsystem **219** to generate and project a cone-like visible aiming beam **221** within the laser scanning field **115** of the system. After the aiming beam **221** is aligned with the bar code symbol to be scanned, the user pulls the trigger switch **104** to its second position. In response, the system controller **150** enables the laser scanning module **105** to generate and project a laser scanning beam through the light transmission window **103**, and across the laser scanning field external to the hand-supportable housing, for scanning an object in the scanning field. The laser scanning beam is generated by laser beam source **112** in response to control signals generated by the system controller **150**. The scanning element (i.e. mechanism) **134** begins to repeatedly scan the selected laser beam across a code symbol residing on an object in the laser scanning field **115**. Then, the light collection optics **106** collects light reflected/scattered from scanned code symbols on the object in the scanning field, and the photo-detector in the photo-detection stage **106**A automatically detects the intensity of collected light (i.e. photonic energy) and pre-amplification stage **106**B generates an analog scan data signal (i.e. bar code pattern signal) corresponding to the light intensity detected during scanning operations. The differentiation stage **107**A and filtering stage **107**C process the analog scan data signals, and the A/D conversion module **107**B converts the processed analog scan data signals into digitized data signals, including the digital raw intensity data signal f(t) and the digital first derivative data signal f'(t). While both the digital raw intensity data signal f(t) and the first derivative data signals f'(t) are transmitted to the programmed decode processor **108** for use in decode processing, only the digital first derivative data signal f'(t) is transmitted to the SDGC module **109** for processing. In other alternative embodiments, however, both the digital raw intensity signal f(t) and the first derivative data signal f'(t) can be transmitted to the SDGC module **109** for use in generating gain control data signals.

The SOS/EOS detector **127** generates a SOS signal upon detecting the start of the first and each subsequent laser beam scanning cycle, and these SOS signals are transmitted to the SDGC module **109** and the programmed decode processor **108**. The SDGC module **109** uses the SOS signal from detector **127** and digital data signal from processor/digitizer **107** to generate digital control data signals for transmission to the digitally-controlled analog signal filtering stage within the analog scan data signal processor/digitizer **107**, to control the gain thereof, during a corresponding scanning cycle, in accordance with the principles of the present disclosure, to be described in greater detail herein. This process is repeated each cycle to control the gain of the filtering stage in processor/digitizer **107**. Also, the programmed decode processor **108** decode processes digitized data signals, and generates symbol character data representative of each bar code symbol scanned by the laser scanning beam. Symbol character data corresponding to the bar codes read by the decoder **108** is then transmitted to the host system via the I/O communication interface **140** which may support either a wired and/or wireless communication link, well known in the art. During laser scanning operations, the system controller **150** automatically generates the necessary control signals for controlling operations within the hand-supportable laser scanning bar code symbol reading system.

Referring to FIG. **9**A, a method will now be described for reading bar code symbols using the laser scanning bar code reader **100**, wherein the gain of an analog signal filtering in the analog scan data signal processor/digitizer **107**, is automatically controlled in a synchronized manner, as the analog scan data signal is collected and processed, and digitized scan data is generated and processed by the SDGC module **109** during each laser beam scanning cycle.

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As indicated in FIG. **9**A, the process orchestrated by system controller **150** begins at the START Block. Then at Block A, the system controller **150** determines if a trigger event has occurred (i.e. whether or not trigger **104** has been manually depressed by the operator upon seeing an object in the laser scanning field and pointing the head portion of the housing towards the object). When the trigger event is detected at Block A, the system controller **150** enables, at Block B, the laser scanning module **105** (including the laser VLD **112**, scanning mechanism and associated electronics and photo-electronics) to scan the object with a laser scanning beam generated by the VLD **112**, and collect and buffer a pair of lines of scan data in buffers **160**, representative of collected scan data from the laser scanned object during both laser scanning directions.

As shown in FIG. **9**A, at Block C, the SDGC process of the present disclosure is carried out in an automatic manner, during each laser scanning cycle, to control the gain of the amplification stage of the light collection and detection module **106**, at the beginning of each laser scanning cycle, and this value is stored and used only for this laser scanning cycle, and will be updated during the beginning of the next scanning cycle, as will be described in detail below with reference to FIGS. **9**A.

As indicated at Block D in FIG. **9**A, the decode processor **108** runs a decode algorithm on the captured lines of scan data buffered in the scan line data buffer **160**. If at Block E, a bar code symbol is decoded, then at Block F, the produced symbol character data is transmitted to the host system, and the system controller returns to Block A.

If, however, at Block E in FIG. **9**A a bar code symbol is not decoded, then the system controller **150** determines at Block G whether or not the maximum scan attempt threshold has been reached, and if not, then the system controller **150** returns to Block B, and resumes the flow as indicated. However, if at Block G, the system controller **150** determines that the maximum scan attempt threshold has been accomplished, then the system controller **150** proceeds to Block H and sends a Failure to Decode notification to the operator, and returns to Block A, as shown.

Specification of Synchronized Digital Gain Control Process of the Third Illustrative Embodiment

FIG. **9**B describes the steps carried out during the synchronized digital gain control (SDGC) process of FIG. **8**, which is automatically and transparently called at Block C in the system control process described in FIG. **9**A, at the beginning of each scanning cycle.

As indicated at Block C**1** in FIG. **9**B, the first step of the SDGC process begins at photo-detection stage (i.e. photo-detector) where collected return laser light is detected by the photo-detector and a corresponding analog scan data signal or analog barcode pattern signal is generated.

As indicated at Block C**2** in FIG. **9**B, the amplification stage amplifies the analog scan data signal, by the gain value determined by the SDGC module **109** during each scanning cycle.

As indicated at Block C**3** in FIG. **9**B, the A/D conversion stage converts the amplified analog scan data signal into a digital scan data signal, and then into time-sampled digital first derivative data signal f'(t) (i.e. comprising digital words or values) representative or indicative of the strength or magnitude in signal level transitions (e.g. first derivative measures), and other signal characteristics that might be useful during decode processing, as well as the synchronized digital gain control process.

As indicated a Block C**4** in FIG. **9**B, a discrete gain calculation/estimation process is carried out at the beginning (i.e. start) of each scanning cycle (i.e. in response to detection of the SOS signal) using a two-step method, namely: performing a histogram analysis on the time-sampled digital first derivative data signal f'(t) indicated at Block C**4**A; and generating a discrete gain value G(s,t) for the amplification stage of the photo-collection and detection module **6**, as indicated at Block C**4**B. In general, the discrete gain signal G(s, t) is a function of the signal strength (e.g. intensity or amplitude), and timing window, [t**1**, t**2**]. The signal strength could be provided by the digital first derivative signal f'(t) as in FIGS. **8**A (and FIG. **6**A), the digital raw intensity data signal f(t) as in FIG. **3**A, or a combination thereof in an alternative embodiment. The timing window t is generated by the SOS/EOS detector which can be implemented in different ways depending on the type of laser scanning system used. The timing window [t**1**, t**2**] is generated by the SOS/EOS detector which can be implemented in different ways depending on the type of laser scanning system used. This ensures that gain change occurs only during the synchronized time window (i.e. when the gate timing signal does to a logical high value) so that the signal has constant gain during each scanning cycle (i.e. laser beam sweep).

In FIG. **9**C, the digital gain calculation/estimation process of the preferred embodiment is described in greater detail, as comprising the following steps: at Block C**4**A-**1**, selecting a time region over which the sampled digital first derivative data signal f'(t) is to be analyzed (e.g. from t**1** to t**0**); at Block C**4**A-**2**, generate a histogram based on the region of the sampled digital scan data signal selected in Block C**4**A-**1**; at Block C**4**A-**3**, calculating a cumulative histogram based on the histogram generated in Block C**4**A-**2**; at Block C**4**B-**1**, calculating the current signal level S(p) corresponding to the frequency of the signal level, p, observed over the selected time region (e.g. 60% or 85%) of the whole cumulative histogram intensity value; and at Block C**4**B-**2**, calculating the discrete gain value G(s,t), for the current scanning cycle, using the following formula: $G(s,t)=S_t/S_p$ where S_t is the target signal level, and S_p is the current signal level corresponding to p (e.g. 60% or 85%) of the whole cumulative histogram intensity. This process has been described in great technical detail above with reference to FIGS. **5**A and **5**B, and will not be repeated to avoid redundancy.

As indicated in the SDGC process of FIG. **9**B, the discrete gain value G(s, t) calculated in Block C**4** is provided to Block C**5**, where a synchronized gain change value ΔG(s, t) is computed, for the current time window (i.e. laser beam scanning cycle), determined by time window block C**6**, driven by SOS/EOS signal generation block C**7**, as described above. The synchronized discrete gain change value ΔG(s,t) (i.e. a digital numerical value) is then transmitted to the digitally-controlled analog amplification stage at Block C**2**, to instantly change the gain of this stage to a new gain value determined by the synchronized discrete gain change value ΔG(s,t). Thus, by selecting the target signal level S_t at an optimum value of system operation, the SDGC module automatically computes and applies the synchronized discrete gain change value ΔG(s, t), during each scanning cycle (i.e. time window) so that the output signal level from the digitally-controlled analog amplification stage closely approaches the target signal level S_t and system performance is optimized.

The SDGC process describes above operates in a manner similar to that described in connection with the first illustrative embodiment, and illustrated in FIGS. **3**B through **3**D.

This SDGC process repeats itself automatically, each and every scanning cycle, in a manner transparent to the system

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user, to maintain the intensity of processed analog scan data signals relatively constant before conversion into corresponding digital data signals.

Some Modifications Which Readily Come To Mind

While synchronized digital gain control (SDGC) module of the present disclosure has been shown implemented inside the programmed decode processor, it is understood that this module could be implemented in other locations, wherever digital signal processing is supported.

As disclosed, the digitized data processed by the SDGC module can be digital raw intensity data and/or digital first derivative data. However, it may also be digital absolute value first derivative data, any other combination of the three different types of digital data.

Also, it is understood that histogram generated by the SDGC module can be analyzed on a whole scan line data or a specific region thereof, and the histogram can be formed with sub-sampling or without sub-sampling.

While the illustrative embodiments disclose the use of a 1D laser scanning module to detect scan bar code symbols on objects, it is understood that a 2D or raster-type laser scanning module can be used as well, to scan 1D bar code symbols, 2D stacked linear bar code symbols, and 2D matrix code symbols, and generate scan data signals for decoding processing.

While various optical code symbol reading systems have been illustrated, it is understood that these laser scanning systems can be packaged in modular compact housings and mounted in fixed application environments, such as on counter-top surfaces, on wall surfaces, and on transportable machines such as forklifts, where there is a need to scan code symbols on objects (e.g. boxes) that might be located anywhere within a large scanning range (e.g. up to 20+ feet away from the scanning system). In such fixed mounted applications, the trigger signal can be generated by manual switches located at a remote location (e.g. within the forklift cab near the driver) or anywhere not located on the housing of the system, as well as by automatically by IR or LED-based object detection subsystems, or manually-actuated trigger switches, well known in the art.

Also, the illustrative embodiments have been described in connection with various types of code symbol reading applications involving 1-D and 2-D bar code structures (e.g. 1D bar code symbols, 2D stacked linear bar code symbols, and 2D matrix code symbols). However, the methods and apparatus can be used to read (i.e. recognize) any machine-readable indicia, dataform, or graphically-encoded form of intelligence, including, but not limited to bar code symbol structures, alphanumeric character recognition strings, handwriting, and diverse dataforms currently known in the art or to be developed in the future. Hereinafter, the term "code symbol" shall be deemed to include all such information carrying structures and other forms of graphically-encoded intelligence.

It is understood that the digital-imaging based bar code symbol reading system of the illustrative embodiments may be modified in a variety of ways which will become readily apparent to those skilled in the art of having the benefit of the novel teachings disclosed herein. All such modifications and variations of the illustrative embodiments thereof shall be deemed to be within the scope of the Claims appended hereto.

The invention claimed is:

1. An indicia reading system, comprising:

a laser scanning module for scanning a laser beam across a laser scanning field in a scanning cycle;

a scan line detector for detecting a start of each scanning cycle performed by the laser scanning module and generating a start of scan (SOS) signal in response to the detection of the start of each scanning cycle;

a photo-detector for detecting the intensity of light reflected from the laser scanning field and generating a first signal corresponding to the detected light intensity;

a signal processor having an amplification stage for amplifying the first signal followed by a processing stage for processing the first signal and converting the processed first signal into a second signal;

a gain control module for, during each scanning cycle, controlling the gain of the processing stage within the signal processor using the SOS signal generated by the scan line detector and the second signal generated by the signal processor; and

a decode processor for processing the second signal and generating data representative of indicia in the scanning field;

wherein, in response to the SOS signal during each scanning cycle, the gain control module processes the second signal, calculates a histogram from the second signal, calculates a cumulative histogram from the calculated histogram, calculates a discrete gain for the scanning cycle from the cumulative histogram, calculates a discrete gain change from the discrete gain, and transmits the discrete gain change as the digital control signal for the scanning cycle to the signal processor.

2. The indicia reading system of claim **1**, wherein:

in response to the SOS signal during each scanning cycle, the gain control module processes the second signal, generates a digital control signal, and transmits the digital control signal to the signal processor; and

the signal processor's processing stage uses the digital control signal to control the gain of the first signal during each scanning cycle.

3. The indicia reading system of claim **1**, comprising at least one light collection optic element for collecting light reflected from the laser scanning field.

4. The indicia reading system of claim **1**, wherein the histogram is calculated using sub-sampling.

5. The indicia reading system of claim **1**, wherein the laser scanning module comprises a rotating polygon or an oscillating mechanism for scanning the laser beam across the laser scanning field.

6. An indicia reading system, comprising:

a laser scanning module for scanning a laser beam across a laser scanning field in a scanning cycle;

a scan line detector for detecting a start of each scanning cycle performed by the laser scanning module and generating a start of scan (SOS) signal in response to the detection of the start of each scanning cycle;

a photo-detector for detecting the intensity of light reflected from the laser scanning field and generating a first signal corresponding to the detected light intensity;

a signal processor having a processing stage for amplifying the first signal, processing the first signal, and converting the processed first signal into a second signal;

a gain control module for, during each scanning cycle, controlling the gain of the processing stage within the signal processor using the SOS signal generated by the scan line detector and the second signal generated by the signal processor; and

a decode processor for processing the second signal and generating data representative of indicia in the scanning field;

wherein, in response to the SOS signal during each scanning cycle, the gain control module processes the second signal, calculates a histogram from the second signal,

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calculates a cumulative histogram from the calculated histogram, calculates a discrete gain for the scanning cycle from the cumulative histogram, calculates a discrete gain change from the discrete gain, and transmits the discrete gain change as the digital control signal for the scanning cycle to the signal processor.

7. The indicia reading system of claim **6**, wherein the gain control module comprises a programmed microprocessor.

8. The indicia reading system of claim **6**, comprising a hand-supportable housing or a fixed-mounted housing.

9. The indicia reading system of claim **6**, wherein the second signal generated by the signal processor comprises the first signal's raw intensity data, first derivative data, and the absolute value of the first derivative data.

10. The indicia reading system of claim **6**, wherein the scan line detector detects an end of each scanning cycle performed by the laser scanning module and generates an end of scan signal in response to the detection of the end of each scanning cycle.

11. An indicia reading system, comprising:

a laser scanning module for scanning a laser beam across a laser scanning field in a scanning cycle;

a scan line detector for detecting a start of each scanning cycle performed by the laser scanning module and generating a start of scan (SOS) signal in response to the detection of the start of each scanning cycle;

a photo-detector for detecting the intensity of light reflected from the laser scanning field and generating a first signal corresponding to the detected light intensity;

a signal processor having a processing stage for processing the first signal and converting the processed first signal into a second signal;

a gain control module for, during each scanning cycle, controlling the gain of the processing stage within the signal processor using the SOS signal generated by the scan line detector and the second signal generated by the signal processor; and

a decode processor for processing the second signal and generating data representative of indicia in the scanning field;

wherein, in response to the SOS signal during each scanning cycle, the gain control module processes the second signal, calculates a histogram from the second signal, calculates a cumulative histogram from the calculated histogram, calculates a discrete gain for the scanning cycle from the cumulative histogram, calculates a discrete gain change from the discrete gain, and transmits the discrete gain change as the digital control signal for the scanning cycle to the signal processor.

12. The indicia reading system of claim **11**, wherein:

in response to the SOS signal during each scanning cycle, the gain control module processes the second signal, generates a digital control signal, and transmits the digital control signal to the signal processor; and

the signal processor's processing stage uses the digital control signal to control the gain of the first signal during each scanning cycle.

13. The indicia reading system of claim **11**, wherein the histogram is calculated using sub-sampling.

14. The indicia reading system of claim **11**, wherein the laser scanning module comprises a rotating polygon or an oscillating mechanism for scanning the laser beam across the laser scanning field.

15. The indicia reading system of claim **11**, wherein the laser scanning module comprises:

a laser source;

a laser drive module for driving the laser source;

a laser scanning mechanism for scanning the laser beam across the laser scanning field.

16. The indicia reading system of claim **11**, wherein the gain control module comprises a programmed microprocessor.

17. The indicia reading system of claim **11**, comprising a hand-supportable housing or a fixed-mounted housing.

18. The indicia reading system of claim **11**, wherein the second signal generated by the signal processor comprises the first signal's raw intensity data, first derivative data, and the absolute value of the first derivative data.

19. The indicia reading system of claim **11**, wherein the scan line detector detects an end of each scanning cycle performed by the laser scanning module and generates an end of scan signal in response to the detection of the end of each scanning cycle.

20. An indicia reading system, comprising:

a laser scanning module for scanning a laser beam across a laser scanning field in a scanning cycle;

a scan line detector for detecting a start of each scanning cycle performed by the laser scanning module and generating a start of scan (SOS) signal in response to the detection of the start of each scanning cycle;

a photo-detector for detecting the intensity of light reflected from the laser scanning field and generating a first signal corresponding to the detected light intensity;

a signal processor having a processing stage for processing the first signal and converting the processed first signal into a second signal comprising the first signal's raw intensity data, first derivative data, and the absolute value of the first derivative data;

a gain control module for, during each scanning cycle, controlling the gain of the processing stage within the signal processor using the SOS signal generated by the scan line detector and the second signal generated by the signal processor; and

a decode processor for processing the second signal and generating data representative of indicia in the scanning field.

* * * * *

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Ackley

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(45) **Date of Patent:** **Jan. 5, 2016**

(54) **SYSTEM AND METHOD FOR DETECTING BARCODE PRINTING ERRORS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/596,757**

(22) Filed: **Jan. 14, 2015**

Related U.S. Application Data

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(51) **Int. Cl.**
G06K 9/00 (2006.01)
G06K 5/02 (2006.01)

(52) **U.S. Cl.**
CPC ***G06K 5/02*** (2013.01)

(58) **Field of Classification Search**
USPC 235/375, 462.01; 347/19
See application file for complete search history.

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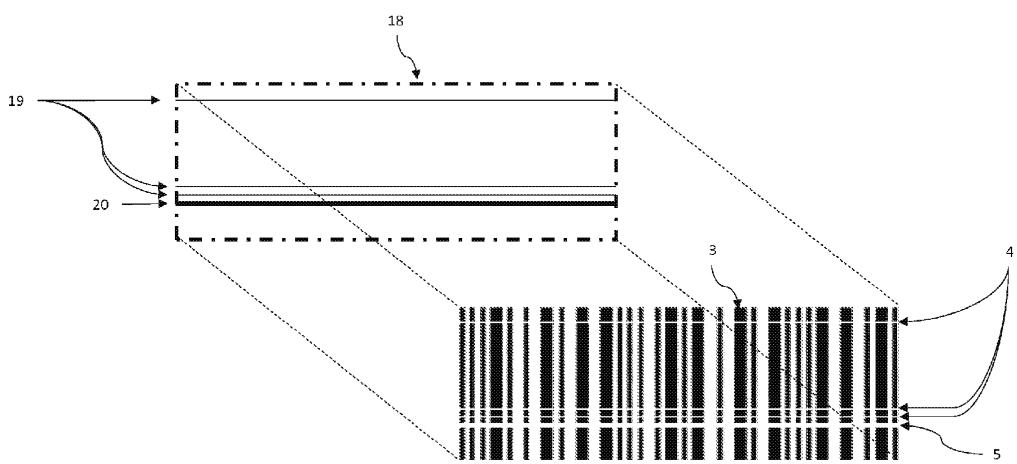
(57) **ABSTRACT**

Barcode verifiers automate the verification process by capturing an image of the printed barcode and analyzing the image according to an industry specification. Industry specifications (e.g., ISO/IEC 15416,15415) identify common printing errors and prescribe test methods for detecting and quantifying these errors. Typically, these tests sample a barcode along one or more scan lines. Print errors that are parallel to these scan lines may be missed by the test. The present invention embraces a system and method to detect unprinted lines in barcodes resulting from a printer malfunction and produce a printer malfunction report with information regarding the quantity, position, and magnitude of these print errors.

20 Claims, 5 Drawing Sheets



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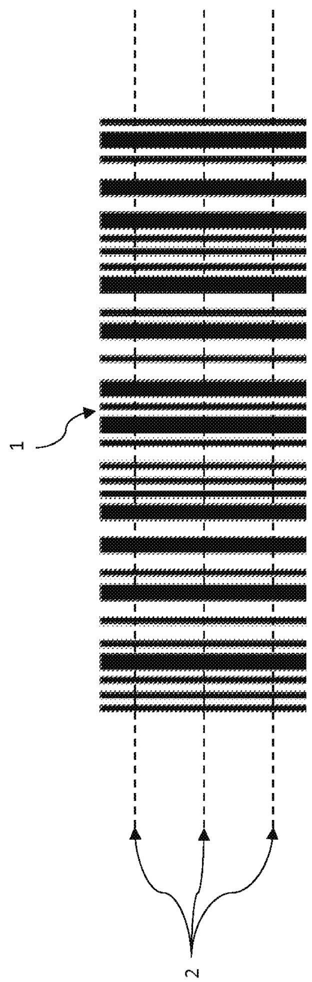

FIG. 1a

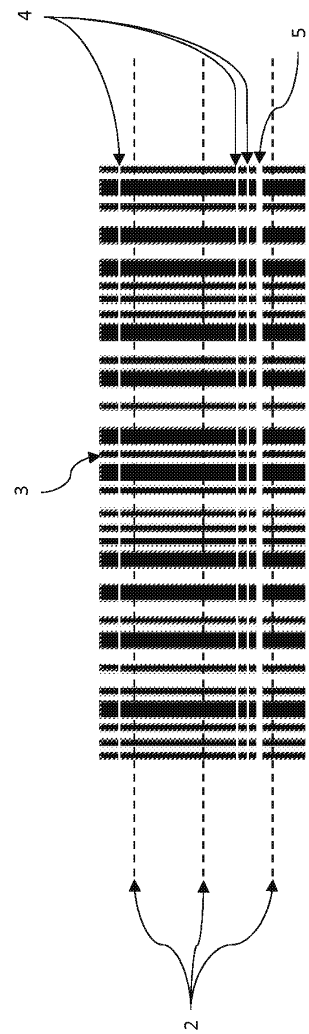

FIG. 1b

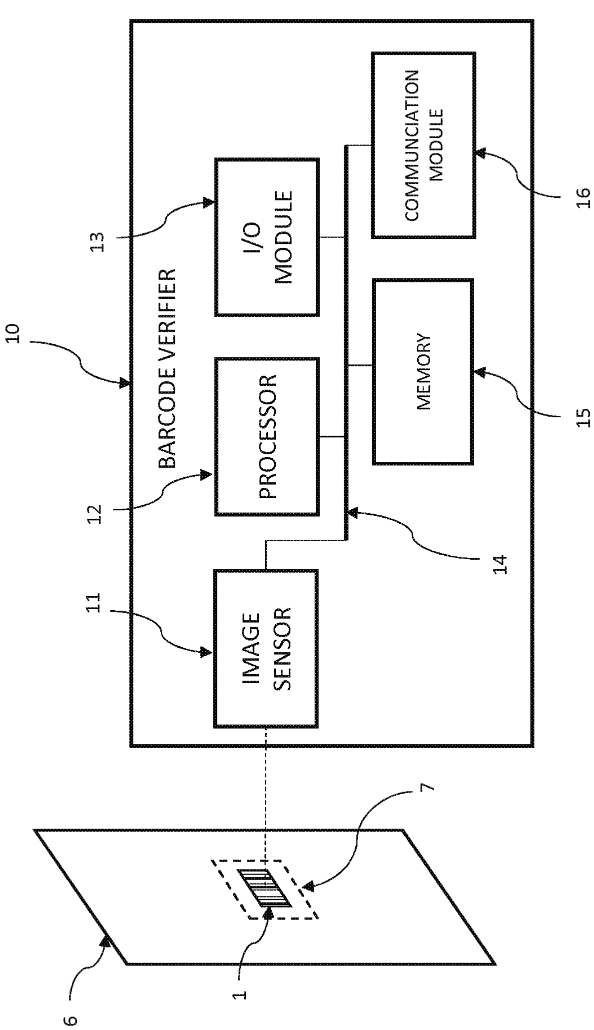
10
BARCODE VERIFIER
11
IMAGE SENSOR
12
PROCESSOR
13
I/O MODULE
14
MEMORY
15
COMMUNCIATION MODULE
16
7
1
6

FIG. 2

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HONEYWELL-00235091

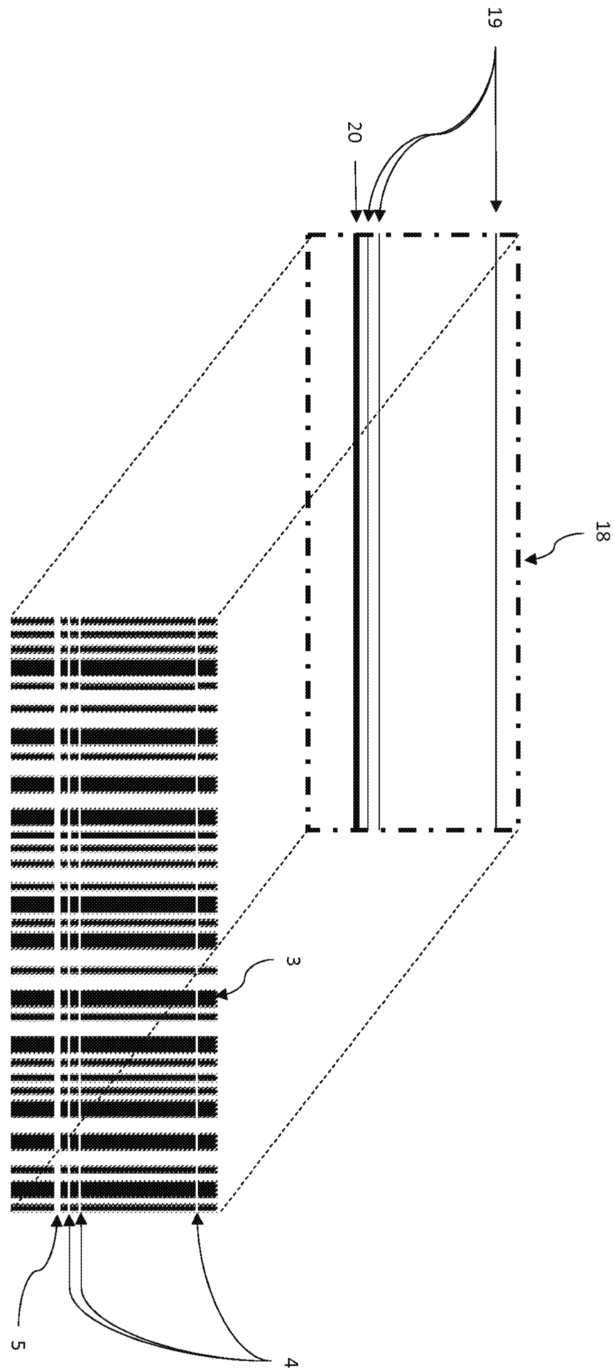

FIG. 3

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HONEYWELL-00235092

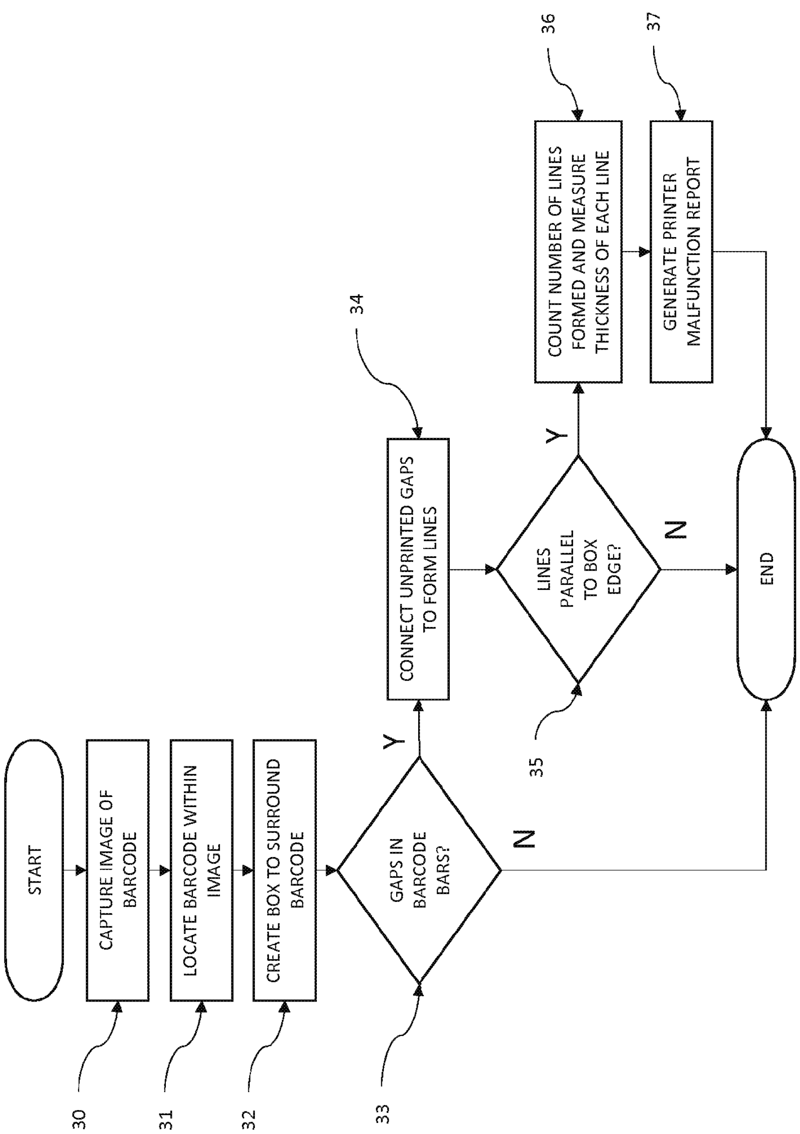

FIG. 4

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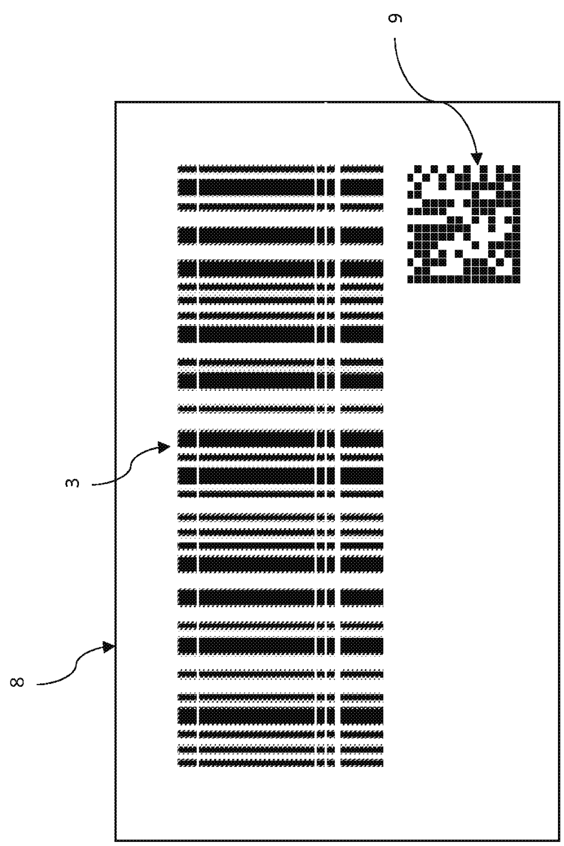

FIG. 5

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SYSTEM AND METHOD FOR DETECTING BARCODE PRINTING ERRORS

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of U.S. Patent Application No. 62/098,174 for a System and Method for Detecting Barcode Printing Errors filed Dec. 30, 2014. The foregoing patent application is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to barcode verifiers and more specifically to a system and method for optically detecting a barcode printing error and generating a printer malfunction report.

BACKGROUND

When printing barcodes, it is important to insure that each barcode can be read (i.e., scanned) by various barcode scanners in a wide range of scanning environments. As a result, industry standards for barcodes have been created to help insure that different scanners operating in different environments can read the same barcode.

Barcode verifiers capture an image of a barcode and analyze the barcode symbol according to test methods prescribed by the industry standards. The barcode verifiers can report the results of these tests and can alert an operator of problems.

The tests often prescribe sampling a barcode symbol at various locations in order to estimate a quality for the entire barcode symbol. For example a linear barcode, which has dark, variable-width barcode bars aligned in parallel and spaced by light, variable-width barcode spaces, may be sampled along parallel lines transverse to the barcode bar/spaces (i.e., along scan lines). Sampling the barcode in this way may cause the barcode verifier to miss certain printing errors that appear parallel to the scan lines. Printing errors of this sort may be common to many barcode printers.

Barcode printers typically use print heads to print a barcode. The print heads in ink jet printers, dot matrix printers, and thermal printers have a linear array of print elements (i.e., dots) to facilitate printing. Printed barcodes are printed dot-by-dot as paper is fed through the printer. When one print element becomes inoperative (e.g., clogged, stuck, burned-out, etc.) an unprinted line (i.e., gap) may appear in the printed barcode symbol. Since these unprinted lines are formed parallel to the test sampling lines (i.e., along the scan line direction), they may go unnoticed.

Therefore, a need exists for barcode verifier that can detect an unprinted line (or lines) in a barcode symbol along the scan line direction and generate a printer malfunction report.

SUMMARY

Accordingly, in one aspect, the present invention embraces a barcode verifier. The barcode verifier includes an imaging module for capturing images of a field of view. The barcode verifier also includes a memory that is communicatively coupled to the imaging module. The memory stores images and a barcode quality verification program. A processor is communicatively coupled to the memory and configured by the barcode quality verification program to create a printer malfunction report by executing a series of ordered steps. The first step is retrieving a stored image from the memory. Next,

a barcode symbol is located in the stored image and an unprinted line (or lines) in the barcode symbol is identified. Using the unprinted line (or lines), a printer malfunction is determined, and finally, the processor executes the step of creating the printer malfunction report.

In an exemplary embodiment of the barcode verifier, the step of locating a barcode symbol in the stored image includes creating a box surrounding the barcode symbol in the stored image. The box includes a top edge and a bottom edge. For one-dimensional (1D) barcode symbologies, the top and bottom edges are lines formed from points located at the ends of the bars. These lines are typically perpendicular to the bars. For two-dimensional (2D) symbologies, the top and bottom lines are found in a similar fashion but use modules in the barcode symbol rather than points at the ends of bars. In some symbologies, lines are included as part of the symbol (e.g., the bottom edge of a data matrix) and may be used to help located the barcode symbol. Optionally a left and right edge of the barcode symbol may be found and included as part of the box.

In another exemplary embodiment of the barcode verifier, a box surrounding the barcode symbol in the stored image is created. The box includes a top edge, a bottom edge, a left edge, and a right edge. The step of identifying an unprinted line in the barcode symbol includes (i) detecting gaps in the barcode symbol, (ii) connecting the detected gaps to form a line, and (iii) identifying a line as an unprinted line if the line is aligned within a reasonable percentage (e.g., 5 percent) of the top or bottom edge of the box.

In another exemplary embodiment of the barcode verifier, a box surrounding the barcode symbol in the stored image is created, gaps in the barcode symbol are detected, and the step of determining a printer malfunction includes calculating the thickness of the gaps relative to the length of an edge of the box or relative to the smallest gap.

In another exemplary embodiment of the barcode verifier, a box surrounding the barcode symbol in the stored image is created, an unprinted line (or lines) is identified, and the step of determining a printer malfunction includes locating the position of each unprinted line relative to the top or bottom edge of the box.

In another exemplary embodiment of the barcode verifier, the step of determining a printer malfunction using the unprinted line (or lines) includes counting the number of unprinted lines.

In another exemplary embodiment of the barcode verifier, the barcode verifier includes a graphical user interface for displaying information to a user. The graphical user interface is communicatively coupled to the processor and configured by the processor to display the printer malfunction report.

In another exemplary embodiment of the barcode verifier, the printer malfunction report is stored to the memory.

In another exemplary embodiment of the barcode verifier, the printer malfunction report includes (i) a printer malfunction alert, (ii) an unprinted-line quantity, (iii) the thickness of each unprinted line, and (iv) the location of each unprinted line.

In another aspect, the present invention embraces a method for generating a printer malfunction report from a barcode image. The method includes the step of using an optical device to capture an image of a barcode, having a plurality of barcode bars. Next, the method includes the steps of locating the barcode within the image and creating a box to surround the located barcode. The box created has (i) a top edge that is perpendicular to the barcode bars and aligned with the top of the barcode bars, and (ii) a bottom edge that is perpendicular to the barcode bars and aligned with the bottom of the barcode bars. After the box is created, the method includes the step of

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detecting unprinted gaps, indicative of a printer malfunction, along each barcode bar. If possible, the edges of the unprinted gaps are connected to form lines that are substantially parallel to the top or bottom edge of the box. Each line is formed with a thickness to fill the corresponding gaps. Next, the method includes the steps of counting the number of lines formed, measuring the thickness of each line, and locating each line with respect to a box edge. If at least one line is formed, then a printer malfunction report is generated. The printer malfunction report includes the number of lines formed, the thickness of each line, and the location of each line with respect to a box edge.

In an exemplary embodiment of the method, a line is considered substantially parallel to the top or bottom edge of the box when the angle between the line and either the top or the bottom edge of the box is less than five degrees.

In another exemplary embodiment of the method, the thickness of each line is measured in printer dot size.

In another exemplary embodiment of the method, the printer malfunction report includes a calculation of the number of adjacent print head elements that are malfunctioning based on the thickness of each line.

In another exemplary embodiment of the method, the printer malfunction report includes guidance for repairing the malfunction.

In another exemplary embodiment of the method, the printer malfunction report includes print quality measurements of the barcode related to industry standards.

In another exemplary embodiment of the method, the optical device is a barcode verifier.

In another exemplary embodiment of the method, the barcode verifier comprises a graphical user interface for displaying the printer malfunction report to a user.

In another exemplary embodiment of the method, the printer malfunction comprises an inoperative heating element in a print head for a thermal printer.

In another exemplary embodiment of the method, the printer malfunction comprises an inoperative jet in a print head for an inkjet printer.

In another exemplary embodiment of the method, the printer malfunction comprises an inoperative pin in a print head for a dot matrix printer.

In another exemplary embodiment of the method, the box created includes (i) a left edge that is parallel to the barcode bars and aligned with the outer edge of the first barcode bar; and (ii) a right edge that is parallel to the barcode bars and aligned with the outer edge of the last barcode bar.

In another aspect, the present invention embraces a barcode scanner for decoding barcodes and verifying barcodes. The barcode scanner includes an imaging module for capturing images of a label. The label includes a user-data barcode symbol encoded with user data and a printer-ID barcode symbol encoded with a printer identity. The barcode scanner also includes a memory that is communicatively coupled to the imaging module. The memory stores the image and a barcode quality verification program. A processor is communicatively coupled to the memory and configured by the barcode quality verification program to create a printer malfunction report by executing a series of ordered steps. The first step is retrieving the image from the memory. The second step is locating the user-data barcode symbol in the retrieved image. The third step is identifying unprinted dots in the user-data barcode symbol. The fourth step is determining a printer malfunction using the unprinted dots. The fifth step is locating the printer-ID barcode symbol in the image. The sixth step is decoding the printer-ID barcode symbol, and the seventh step is creating a printer malfunction report. The printer malfunction report includes the printer malfunction and the printer identity.

The foregoing illustrative summary, as well as other exemplary objectives and/or advantages of the invention, and the manner in which the same are accomplished, are further explained within the following detailed description and its accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1***a* graphically depicts an exemplary barcode symbol and exemplary scan lines.

FIG. **1***b* graphically depicts exemplary scan lines and an exemplary barcode symbol having unprinted gaps in the barcode bars due to a printer malfunction.

FIG. **2** schematically depicts a block diagram of a barcode verifier according to an embodiment of the present invention.

FIG. **3** graphically depicts an exemplary barcode symbol having unprinted gaps as well as the box and lines used in the creation of printer malfunction report.

FIG. **4** schematically depicts a flowchart of an exemplary method for determining a printer malfunction from a barcode image.

FIG. **5**. graphically depicts an exemplary label with a user-data barcode symbol and a printer-ID barcode symbol.

DETAILED DESCRIPTION

The present invention embraces a barcode verifier for detecting print errors in a printed barcode. Barcodes are optical machine-readable representations of data. They may use one or two-dimensional patterns and may be black-and-white or color. One exemplary barcode, shown in FIG. **1**, is a linear barcode **1** that includes dark barcode bars and light barcode spaces. The barcode bars and barcode spaces may be different widths to form various patterns. The barcode bars are elongated and are scanned along a scan line perpendicular to the elongated direction.

Scanning printed barcodes requires good print quality. To insure that a printed barcode will be properly scanned, this print quality must be evaluated. Industry standards such as ISO/IEC 15416 and ISO/IEC 15415 serve as guidelines for evaluating barcode quality. In these standards, various tests are described and grading criteria for the test results are established. A printed barcode may be tested to insure that it meets a minimum grade to insure that scan errors are minimized. This evaluation process may be automated with barcode verifiers.

Barcode verifiers are optical devices that capture and analyze images of barcodes. The analysis of an image typically requires the location and segmentation of a barcode symbol within the image. The barcode symbol is tested according to an array of tests specified by a selected standard. Often, additional non-graded parameters are also evaluated by the verifiers (e.g., ink spread) to facilitate additional process control. By monitoring the reports from the barcode verifiers, printing errors may be found and remedied with little loss and before delivering barcodes that are difficult or impossible to scan.

Automated testing of barcodes may not be perfect. Most quality control tests utilize samples to manage complexity while still providing a good estimate of the tested item's quality. In this way, barcode verifiers may sample a barcode by scanning the barcode symbol at various locations. FIG. **1***a* shows an exemplary barcode **1**. A verifier may capture an image of a barcode **1** and analyze its quality along a sampling

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of scan lines **2**. These scan lines may provide a good estimate of the print quality but may miss imperfections, especially when the imperfections are parallel to the scan lines **2**.

FIG. **1***b* graphically depicts an exemplary barcode symbol with print errors **3**. The unprinted gaps along each barcode bar may be due to a printer malfunction. These gaps combine to form unprinted lines **4**,**5** that run parallel to the scan lines **2**. Here, the scan lines **2** in FIG. **1***b* do not encounter the unprinted lines **4**,**5**. A verifier testing this barcode **3** with these scan lines **2** would not detect these printing errors.

The printing defects described so far are common to barcode printers. Barcodes printers may be Ink jet printers, dot matrix printers, or thermal printers. Each of these printers uses a print head. The print head has a linear array of print elements to form a printed mark (i.e., dot). The print elements print a barcode dot-by-dot as paper is fed through the printer and past the print head (which may also move during the printing process). When one print element in the print head becomes inoperative (e.g., clogged, stuck, burned-out, etc.) an unprinted gap may appear in each barcode bar. Due to the nature of the printing process, the gaps appear in each barcode bar at the same height. As a result, these gaps appear as an unprinted line in the barcode symbol running perpendicular to the barcode bar (i.e., parallel to a scan line). In some cases, multiple unprinted lines may occur due to multiple inoperative print head elements. These unprinted lines appear parallel to one another and are typically the same thickness (i.e., one dot), however sometimes, the gaps may be larger, forming thick lines. Thick lines are formed when adjacent print head elements are inoperative. In FIG. **1***b* the thick unprinted line **5** results from adjacent inoperative print head elements. By measuring line thickness and correlating this measurement to print head element size, the number of inoperative print head elements may be computed.

The present invention addresses the need for a system and method to detect the unprinted lines caused by a print head element malfunction. Such a system/method can generate a printer malfunction report to quantify these print errors. A printer malfunction report may include information regarding the number of unprinted lines, the location of the unprinted lines, and the thickness of each unprinted line. This information may be used to understand and remedy the print head malfunction causing the unprinted lines.

Existing barcode verifiers may assign a lower grade to barcodes with unprinted lines but this assignment is often random. In some cases, the verifier may detect the unprinted lines, while in other cases the verifier may not detect the unprinted lines. This variability leads to grading inconsistencies, and grading may not be repeatable. What is more, these barcode verifiers may detect the unprinted lines, but they cannot identify the printer malfunction or provide other information to help remedy it.

The present invention embraces an optical device that can report (i) the presence of an unprinted line, (ii) the cause of the unprinted line (i.e., printer malfunction), and (iii) explain the malfunction (e.g., number of inoperative print head elements). The optical device may be a barcode verifier or a barcode scanner configured to perform barcode verification.

Typical barcode scanners attempt to read barcode symbol data only (i.e., no verification). While hand-held scanners (e.g. 2D imagers) cannot perform full verification without some type of mounting and or lighting procedure, they can perform the analysis embraced by the present invention. A barcode scanner enabled with a barcode quality verification program can read a barcode symbol, evaluate missing lines, and create a maintenance report (i.e., printer malfunction report). Consequently, a barcode scanner can trigger an alert informing a user that a printer is close to failure before the printer produces unreadable barcodes.

The printer malfunction report described could take many forms. The report might be ordered data stored in memory and accessed by reporting software. For example, a printer malfunction report may enhance/support other barcode verifier tests/evaluations (e.g., ISO/IEC 15416 and/or 15415 tests). The printer malfunction report may also be part of a quality control process and provide alerts to an operator when a print head exhibited certain behavior (e.g., the number of unprinted lines exceeded a threshold). The printer malfunction report may be used by an operator to troubleshoot or diagnose a printer issue.

The printer malfunction report may be displayed by a graphical user interface (e.g. integrated with a barcode verifier) to display results to a human operator. The displayed results could comprise data from many barcode tests. The displayed results could allow an operator to monitor print head deterioration and replace the print head before any unreadable barcode symbols were printed.

FIG. **2** schematically depicts a block diagram of a barcode verifier according to an embodiment of the present invention. The barcode verifier **10** captures an optical image of a barcode **1** within a field of view **7**. The barcode is printed on a target item 6 (e.g., label, packaging, etc.). The barcode may be one-dimensional (e.g., linear barcode) or two-dimensional (e.g., Data Matrix, PDF417, Aztec Code, QR Code, etc.). The barcode verifier captures an image of the barcode using an image sensor **11**. The image sensor **11** uses an imaging lens (or lenses) to form a real image of the field of view **7** on an array of photo sensors (e.g., CCD, CMOS sensor, etc.). Electronic signals from the photo sensors are used to create black-and-white or color images. The images are stored on a memory **15** (e.g., read-only memory (ROM), flash memory, a hard-drive, etc.) and may be recalled by a processor **12** for barcode verification.

The processor **12** is configured by a barcode quality verification program stored in memory **15** to analyze the barcode and create a printer malfunction report. The processor **12** is configured by the program to execute the steps of (i) retrieving a stored image from the memory, (ii) locating a barcode symbol in the stored image, (iii) identifying an unprinted line or lines in the barcode symbol, (iv) determining a printer malfunction using the unprinted line or lines, and (v) creating a printer malfunction report.

In the step of locating a barcode symbol in the stored image, a box is created to surround the barcode symbol. FIG. **3** graphically depicts an exemplary barcode symbol **3** as well as the box **18**. The program's step of identifying an unprinted line in the barcode symbol configures the processor to execute the steps of analyzing the image to (i) detect gaps in the barcode symbol **4**,**5** (i.e., gaps in each barcode bar), (ii) connect the detected gaps to form unprinted lines **19**,**20**, and (iii) identifying a line as an unprinted line if the line is aligned within 5% of the top or bottom edge of the box. A line is aligned (i.e. parallel) within 5% of the top or bottom edge of the box if the angle formed between these line **19**,**20** and the top/bottom of the box **18** is less than five degrees (i.e., 5% of 90 degrees is roughly 5 degrees)

Once the box and the lines are created, the processor **12** may analyze the lines to create metrics reported in a printer malfunction report. One such metric is the number of lines. For the example shown in FIG. **3** there are four lines.

Another metric is line thickness. Line thickness may be expressed relative to a box dimension (e.g., percentage) or

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may be converted to a printer dot size. For the example shown in FIG. **3**, there are three thin lines **19** (e.g., one dot) and on thick line **20**.

Another metric computed may be line position. Thick lines may be processed to compute the number of adjacent print head elements that are malfunctioning. The position may be expressed relative to coordinate system created by the box (e.g., height from the bottom). Again, this may also be converter to printer dot size to correlate these numbers to the printer's print head.

The printer malfunction report may be stored in the memory **15** and communicated to a user via an input/output (I/O) module **13**. The I/O module **13** may be integrated with the barcode verifier or a separate device that is communicatively coupled to the barcode verifier. In either case, the I/O module **13** may include a graphical user interface and may display visual and/or auditory information and receive information from a user (e.g., typed, touched, spoken, etc.).

In some embodiments, the barcode verifier **10** may communicatively connected using a communication module **16** to a computer or a network via a wired or wireless data link. In a wireless configuration, the communication module may communicate with a host device over the network via a variety of communication protocols (e.g., WI-FI®, BLUETOOTH®), CDMA, TDMA, or GSM).

The subsystems in the barcode verifier **10** are electrically connected via a couplers (e.g., wires, traces, etc.) to form an interconnection subsystem **14**. The interconnection system **14** may include power buses or lines, data buses, instruction buses, address buses, etc., which allow operation of the modules/subsystems and the interaction there between.

FIG. **4** schematically depicts a flowchart of an exemplary method for determining a printer malfunction from a barcode image. The method begins by capturing an image of a barcode **30** (e.g., linear barcode) using an optical device (e.g., barcode verifier). Next, the barcode is located within the image of the barcode **31** and a box is created **32** to surround the spatial extent of the located barcode within the image. The barcode bars are then analyzed (e.g., edge detection) to find any unprinted gaps indicative of a printer malfunction. If no gaps are found then no printer malfunction is found and the process ends. If, however, gaps in the barcode bars are found **33**, then the gaps are connected form lines within the box **34**. Each line is created to fill the gaps so that the line thickness represents the gap size in the barcode bars. The lines formed are checked to insure that they are parallel to the box edge **35** (e.g., angle between lines and box top is less than five degrees). If the lines are not parallel then some other defect has caused the print error. If the lines are parallel **35** then the number of lines are counted and the thickness of each line is measured **36**. Finally, a printer malfunction report including the number of lines formed, the thickness of each line, and the location of each line with respect to a box edge is generated **37**.

In some embodiments, information regarding the printer that created a barcode symbol (i.e., the printer ID) may be encoded within a 1D or 2D barcode symbol printed on the same label as the barcode symbol containing user data. Here, the term label may represents any substrate carrying a symbol created by a printer. For example, a label may include a paper/plastic substrate onto which a barcode is printed. Alternatively, a label may include some faceplate material engraved with a barcode. Further, a label may be thought of as a barcode marked directly onto the surface of an item.

When a barcode scanner (or barcode verifier) detects unprinted dots (or lines) on a label, the printer ID symbol on the label may be decoded to identify the printer that created the printing error. This identification may facilitate service for

the printer. Further error/printer data may be collected over time. Statistics may be applied to the collected data to aid in understanding the errors associated with a printer (or printers). This statistical information could be particularly helpful in, for example, creating repair and/or maintenance schedules for printers.

An exemplary label **8** is shown in FIG. **5**. The label includes two symbols. The first symbol is linear barcode **3** representing the user data (i.e., user-data barcode symbol). This first symbol is the symbol scanned by an application to perform a function (e.g., luggage identification). The second symbol on the label **8** is a printer identification barcode symbol (i.e., printer-ID barcode symbol) **9**. The printer-ID barcode symbol **9** is encoded with the identity of the printer that printed the label (i.e., the printer identity).

The printer-ID barcode symbol **9** in FIG. **5** is a data matrix symbol encoded with a printer identity (e.g., "PRINTER 24"). The printer-ID barcode symbol **9** is used to identify the printer that created the label **8** to facilitate maintenance and/or repair functions. While printer errors may also affect the printer-ID barcode symbol **9**, the present invention may report errors for these symbols as well as the user-data barcode symbol **3**.

To supplement the present disclosure, this application incorporates entirely by reference the following commonly assigned patents, patent application publications, and patent applications:

U.S. Pat. No. 6,832,725; U.S. Pat. No. 7,128,266;
U.S. Pat. No. 7,159,783; U.S. Pat. No. 7,413,127;
U.S. Pat. No. 7,726,575; U.S. Pat. No. 8,294,969;
U.S. Pat. No. 8,317,105; U.S. Pat. No. 8,322,622;
U.S. Pat. No. 8,366,005; U.S. Pat. No. 8,371,507;
U.S. Pat. No. 8,376,233; U.S. Pat. No. 8,381,979;
U.S. Pat. No. 8,390,909; U.S. Pat. No. 8,408,464;
U.S. Pat. No. 8,408,468; U.S. Pat. No. 8,408,469;
U.S. Pat. No. 8,424,768; U.S. Pat. No. 8,448,863;
U.S. Pat. No. 8,457,013; U.S. Pat. No. 8,459,557;
U.S. Pat. No. 8,469,272; U.S. Pat. No. 8,474,712;
U.S. Pat. No. 8,479,992; U.S. Pat. No. 8,490,877;
U.S. Pat. No. 8,517,271; U.S. Pat. No. 8,523,076;
U.S. Pat. No. 8,528,818; U.S. Pat. No. 8,544,737;
U.S. Pat. No. 8,548,242; U.S. Pat. No. 8,548,420;
U.S. Pat. No. 8,550,335; U.S. Pat. No. 8,550,354;
U.S. Pat. No. 8,550,357; U.S. Pat. No. 8,556,174;
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U.S. Pat. No. 8,559,767; U.S. Pat. No. 8,599,957;
U.S. Pat. No. 8,561,895; U.S. Pat. No. 8,561,903;
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U.S. Pat. No. 8,571,307; U.S. Pat. No. 8,579,200;
U.S. Pat. No. 8,583,924; U.S. Pat. No. 8,584,945;
U.S. Pat. No. 8,587,595; U.S. Pat. No. 8,587,697;
U.S. Pat. No. 8,588,869; U.S. Pat. No. 8,590,789;
U.S. Pat. No. 8,596,539; U.S. Pat. No. 8,596,542;
U.S. Pat. No. 8,596,543; U.S. Pat. No. 8,599,271;
U.S. Pat. No. 8,599,957; U.S. Pat. No. 8,600,158;
U.S. Pat. No. 8,600,167; U.S. Pat. No. 8,602,309;
U.S. Pat. No. 8,608,053; U.S. Pat. No. 8,608,071;
U.S. Pat. No. 8,611,309; U.S. Pat. No. 8,615,487;
U.S. Pat. No. 8,616,454; U.S. Pat. No. 8,621,123;
U.S. Pat. No. 8,622,303; U.S. Pat. No. 8,628,013;
U.S. Pat. No. 8,628,015; U.S. Pat. No. 8,628,016;
U.S. Pat. No. 8,629,926; U.S. Pat. No. 8,630,491;
U.S. Pat. No. 8,635,309; U.S. Pat. No. 8,636,200;
U.S. Pat. No. 8,636,212; U.S. Pat. No. 8,636,215;
U.S. Pat. No. 8,636,224; U.S. Pat. No. 8,638,806;
U.S. Pat. No. 8,640,958; U.S. Pat. No. 8,640,960;
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U.S. Pat. No. 8,757,495; U.S. Pat. No. 8,760,563;
U.S. Pat. No. 8,763,909; U.S. Pat. No. 8,777,108;
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U.S. patent application Ser. No. 29/436,337 for an Electronic Device, filed Nov. 5, 2012 (Fitch et al.);
U.S. patent application Ser. No. 13/771,508 for an Optical Redirection Adapter, filed Feb. 20, 2013 (Anderson);
U.S. patent application Ser. No. 13/852,097 for a System and Method for Capturing and Preserving Vehicle Event Data, filed Mar. 28, 2013 (Barker et al.);
U.S. patent application Ser. No. 13/902,110 for a System and Method for Display of Information Using a Vehicle-Mount Computer, filed May 24, 2013 (Hollifield);
U.S. patent application Ser. No. 13/902,144, for a System and Method for Display of Information Using a Vehicle-Mount Computer, filed May 24, 2013 (Chamberlin);
U.S. patent application Ser. No. 13/902,242 for a System For Providing A Continuous Communication Link With A Symbol Reading Device, filed May 24, 2013 (Smith et al.);
U.S. patent application Ser. No. 13/912,262 for a Method of Error Correction for 3D Imaging Device, filed Jun. 7, 2013 (Jovanovski et al.);
U.S. patent application Ser. No. 13/912,702 for a System and Method for Reading Code Symbols at Long Range Using Source Power Control, filed Jun. 7, 2013 (Xian et al.);
U.S. patent application Ser. No. 29/458,405 for an Electronic Device, filed Jun. 19, 2013 (Fitch et al.);
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U.S. patent application Ser. No. 13/927,398 for a Code Symbol Reading System Having Adaptive Autofocus, filed Jun. 26, 2013 (Todeschini);
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U.S. patent application Ser. No. 14/460,387 for APPARATUS FOR DISPLAYING BAR CODES FROM LIGHT EMITTING DISPLAY SURFACES filed Aug. 15, 2014 (Van Horn et al.);

U.S. patent application Ser. No. 14/460,829 for ENCODED INFORMATION READING TERMINAL WITH WIRELESS PATH SELECTION CAPABILITY, filed Aug. 15, 2014 (Wang et al.);

U.S. patent application Ser. No. 14/462,801 for MOBILE COMPUTING DEVICE WITH DATA COGNITION SOFTWARE, filed on Aug. 19, 2014 (Todeschini et al.);

U.S. patent application Ser. No. 14/446,387 for INDICIA READING TERMINAL PROCESSING PLURALITY OF FRAMES OF IMAGE DATA RESPONSIVELY TO TRIGGER SIGNAL ACTIVATION filed Jul. 30, 2014 (Wang et al.);

U.S. patent application Ser. No. 14/446,391 for MULTIFUNCTION POINT OF SALE APPARATUS WITH OPTICAL SIGNATURE CAPTURE filed Jul. 30, 2014 (Good et al.);

U.S. patent application Ser. No. 29/486,759 for an Imaging Terminal, filed Apr. 2, 2014 (Oberpriller et al.);

U.S. patent application Ser. No. 29/492,903 for an INDICIA SCANNER, filed Jun. 4, 2014 (Zhou et al.); and

U.S. patent application Ser. No. 29/494,725 for an IN-COUNTER BARCODE SCANNER, filed Jun. 24, 2014 (Oberpriller et al.).

In the specification and/or figures, typical embodiments of the invention have been disclosed. The present invention is not limited to such exemplary embodiments. The use of the term "and/or" includes any and all combinations of one or more of the associated listed items. The figures are schematic representations and so are not necessarily drawn to scale. Unless otherwise noted, specific terms have been used in a generic and descriptive sense and not for purposes of limitation.

The invention claimed is:

1. A barcode verifier, comprising:

an imaging module for capturing images of a field of view;

a memory communicatively coupled to the imaging module and configured to store images and a barcode quality verification program; and

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a processor communicatively coupled to the memory configured by the barcode quality verification program to execute the ordered steps of:

(i) retrieving a stored image from the memory, (ii) locating a barcode symbol in the stored image, (iii) identifying an unprinted line or lines in the barcode symbol, (iv) determining a printer malfunction using the unprinted line or lines, and (v) creating a printer malfunction report.

2. The barcode verifier according to claim **1**, wherein the step of locating a barcode symbol in the stored image comprises creating a box surrounding the barcode symbol in the stored image, wherein the box comprises a top edge, a bottom edge, a left edge, and a right edge, each edge corresponding to a respective barcode symbol edge.

3. The barcode verifier according to claim **2**, wherein the step of identifying an unprinted line in the barcode symbol comprises:

(i) detecting gaps in the barcode symbol, (ii) connecting the detected gaps to form a line, and (iii) identifying a line as an unprinted line if the line is aligned within 5% of the top or bottom edge.

4. The barcode verifier according to claim **3**, wherein the step of determining a printer malfunction using the unprinted line or lines, comprises calculating a thickness of the gaps relative to a length of an edge of the box.

5. The barcode verifier according to claim **2**, wherein the step of determining a printer malfunction using the unprinted line or lines, comprises locating the position of each unprinted line relative to the top or bottom edge of the box.

6. The barcode verifier according to claim **1**, wherein the step of determining a printer malfunction using the unprinted line or lines, comprises counting the number of unprinted lines.

7. The barcode verifier according to claim **1**, comprising a graphical user interface for displaying information to a user, the graphical user interface communicatively coupled to the processor and configured by the processor to display the printer malfunction report.

8. The barcode verifier according to claim **1**, wherein the printer malfunction report comprises:

(i) a printer malfunction alert, (ii) an unprinted-line quantity, (iii) a thickness of each unprinted line, and (iv) a location of each unprinted line.

9. A method for generating a printer malfunction report from a barcode image, the method comprising:

capturing an image of a barcode using an optical device, the barcode comprising a plurality of barcode bars;

locating the barcode within the image of the barcode;

creating a box to surround the located barcode, wherein the box comprises:

(i) a top edge perpendicular to the barcode bars and aligned with the top of the barcode bars and (ii) a bottom edge perpendicular to the barcode bars and aligned with the bottom of the barcode bars;

detecting unprinted gaps along each barcode bar, the gaps indicative of a printer malfunction;

if possible, connecting the unprinted gaps to form lines that are substantially parallel to the top or bottom edge of the box, each line having a thickness to fill the corresponding unprinted gaps;

counting the number of lines formed;

measuring the thickness of each line;

locating each line with respect to a box edge; and

if at least one line is formed, then generating a printer malfunction report comprising the number of lines formed, the thickness of each line, and the location of each line with respect to a box edge.

10. The method according to claim **9**, wherein a line is substantially parallel to the top or bottom edge of the box when the angle between the line and either the top or bottom edge of the box is less than five degrees.

11. The method according to claim **9**, wherein the thickness of each line is measured in printer dot size.

12. The method according to claim **9**, wherein the printer malfunction report comprises a calculation of the number of adjacent print-head elements that are malfunctioning based on the thickness of each line.

13. The method according to claim **9**, wherein the printer malfunction report comprises guidance for repairing the malfunction.

14. The method according to claim **9**, wherein the optical device is a barcode verifier.

15. The method according to claim **14**, wherein the barcode verifier comprises a graphical user interface for displaying the printer malfunction report to a user.

16. The method according to claim **9**, wherein the printer malfunction comprises an inoperative heating element in a print head for a thermal printer.

17. The method according to claim **9**, wherein the printer malfunction comprises an inoperative jet in a print head for an inkjet printer.

18. The method according to claim **9**, wherein the printer malfunction comprises an inoperative pin in a print head for a dot matrix printer.

19. The method according to claim **9**, wherein the box created to surround the located barcode comprises (i) a left edge parallel to the barcode bars and aligned with the outer edge of the first barcode bar and (ii) a right edge parallel to the barcode bars and aligned with the outer edge of the last barcode bar.

20. A barcode scanner for decoding barcodes and verifying barcodes, the barcode scanner comprising:

an imaging module for capturing an image of a label, the label comprising a user-data barcode symbol encoded with user data and a printer-ID barcode symbol encoded with a printer identity;

a memory communicatively coupled to the imaging module and configured to store the image and a barcode quality verification program; and

a processor communicatively coupled to the memory and configured by the barcode quality verification program to execute the ordered steps of:

(i) retrieving the image from the memory, (ii) locating the user-data barcode symbol in the retrieved image, (iii) identifying unprinted dots in the user-data barcode symbol, (iv) determining a printer malfunction using the unprinted dots, (v) locating the printer-ID barcode symbol in the image, (vi) decoding the printer-ID barcode symbol, and (vii) creating a printer malfunction report comprising the printer malfunction and the printer identity.

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(12) **United States Patent**
Ackley

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(54) **ENHANCED MATRIX SYMBOL ERROR CORRECTION METHOD**

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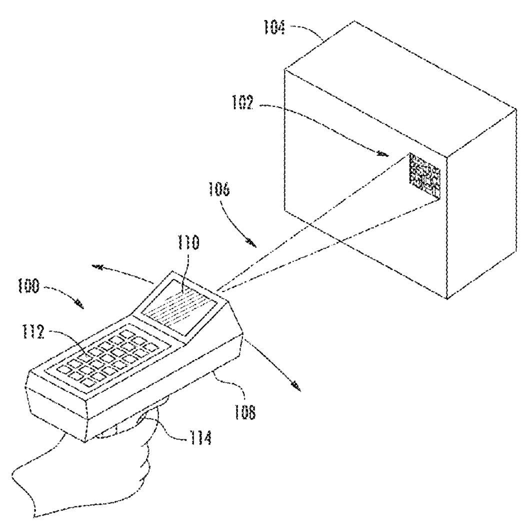
(57) **ABSTRACT**

Systems and methods illustrated herein disclose error correction of a two-dimensional (2D) symbol. The systems and methods include reading, by a hardware processor, a plurality of codewords in the 2D symbol. Further, the systems and methods include identifying, by the hardware processor of, an optically ambiguous codeword of the plurality of codewords in the 2D symbol. The optically ambiguous codeword corresponds to a codeword with a minimum interior contrast level below a predefined minimum interior contrast level. Further, the systems and methods include correcting, by the hardware processor, errors in the optically ambiguous codeword based on, a location of the optically ambiguous codeword and an erroneous decoded value associated with the optically ambiguous codeword.

19 Claims, 8 Drawing Sheets



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See application file for complete search history.

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2014/0131438	A1	5/2014	Kearney	
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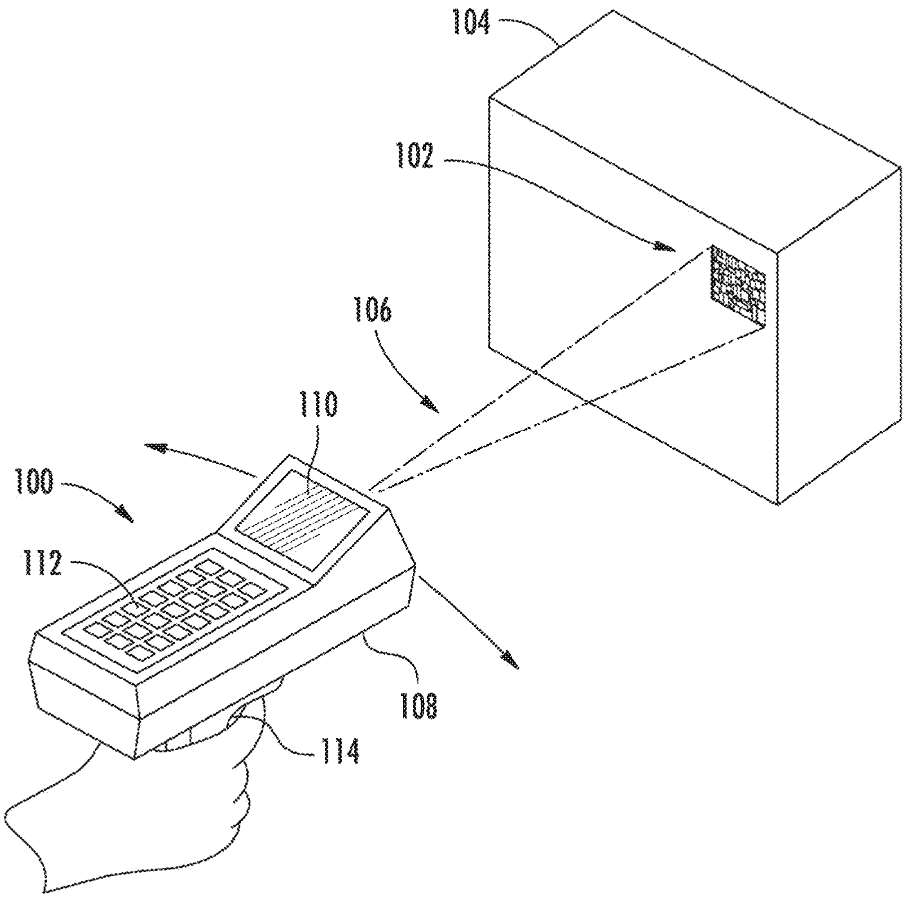

FIG. 1

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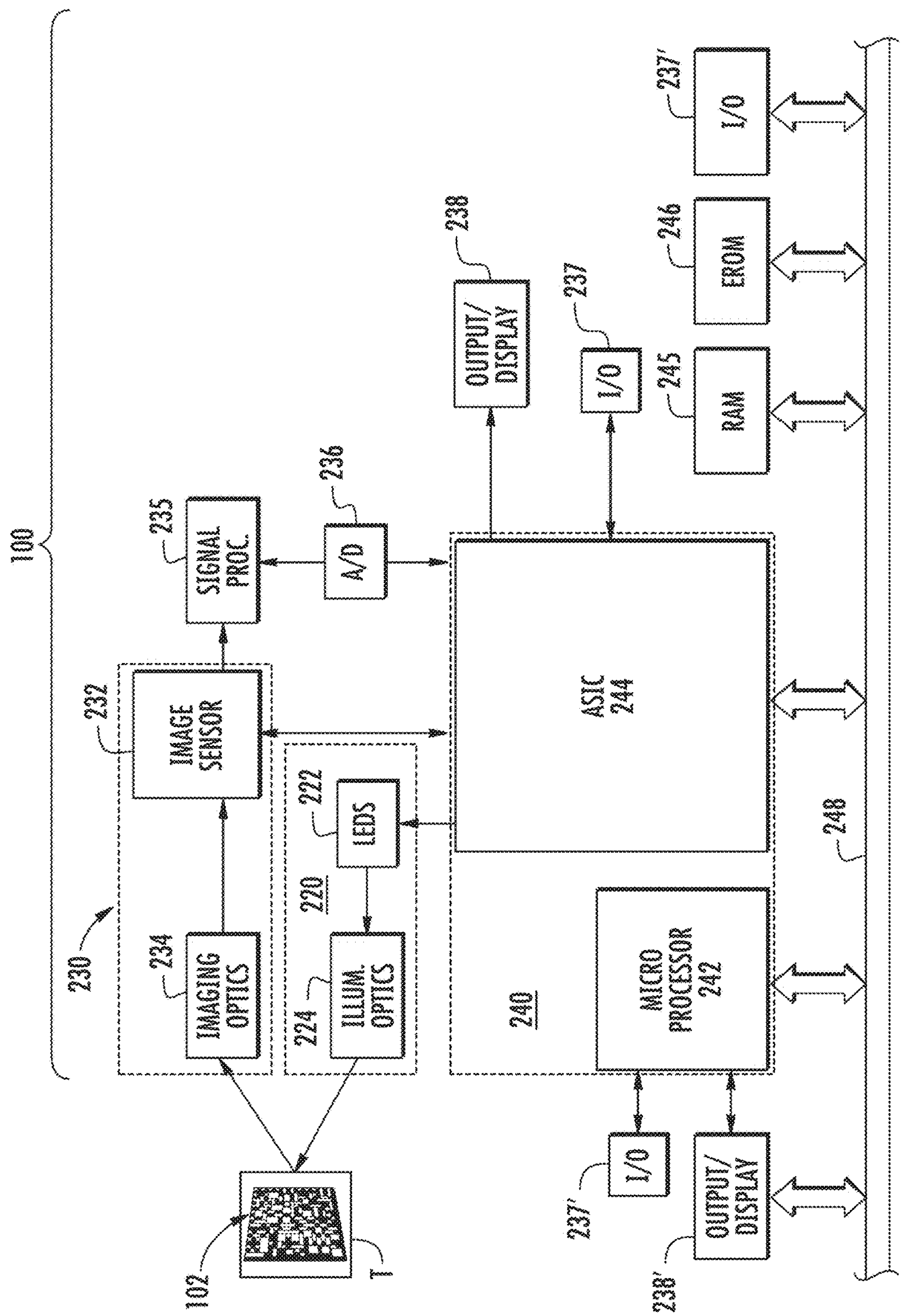
FIG. 2



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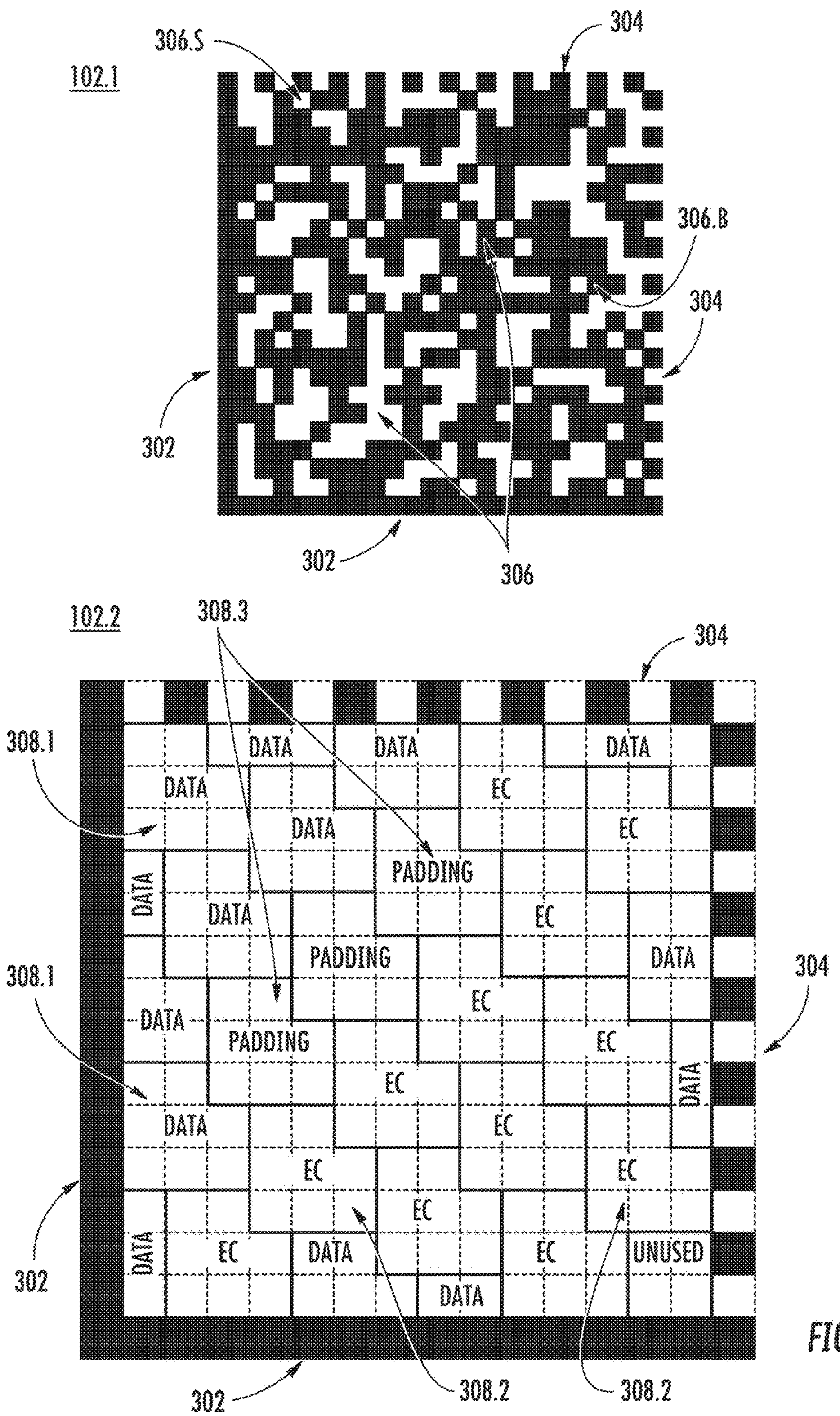

102.1
306.S
304
306.B
304
302
302
306
102.2
308.3
304
308.1
DATA
DATA
DATA
DATA
EC
EC
DATA
PADDING
DATA
DATA
EC
PADDING
DATA
308.1
304
DATA
EC
PADDING
EC
EC
DATA
DATA
EC
EC
EC
EC
302
DATA
EC
DATA
EC
UNUSED
DATA
302
308.2
308.2

FIG. 3

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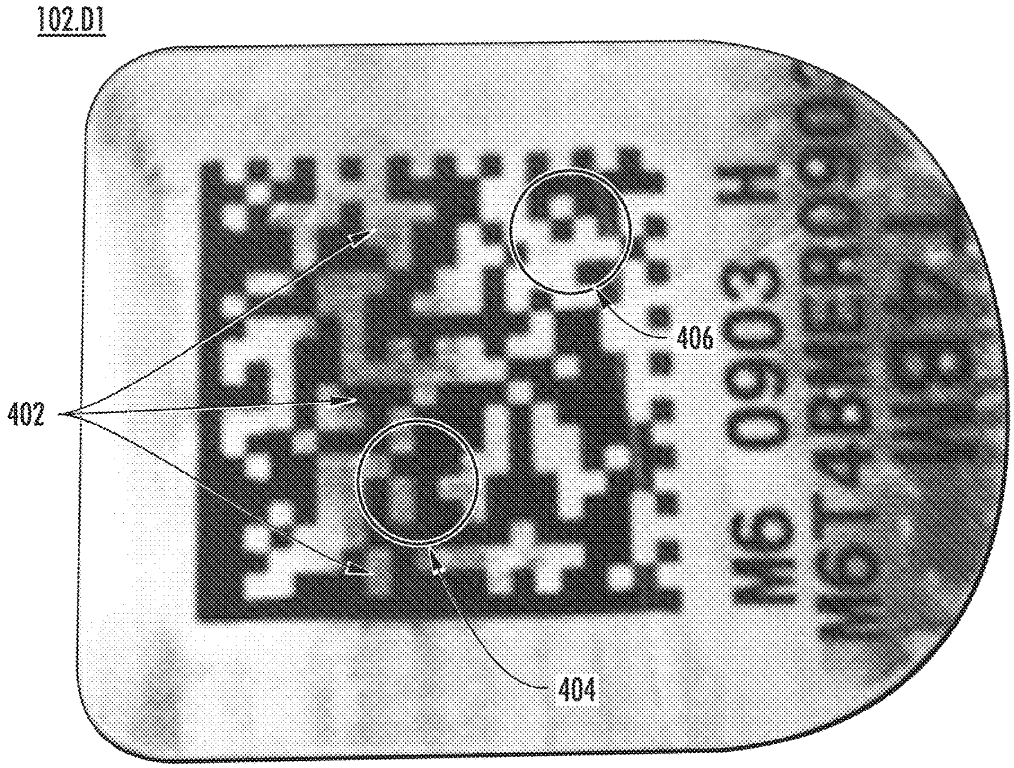
102.D1
402
406
404
M6 0903 H

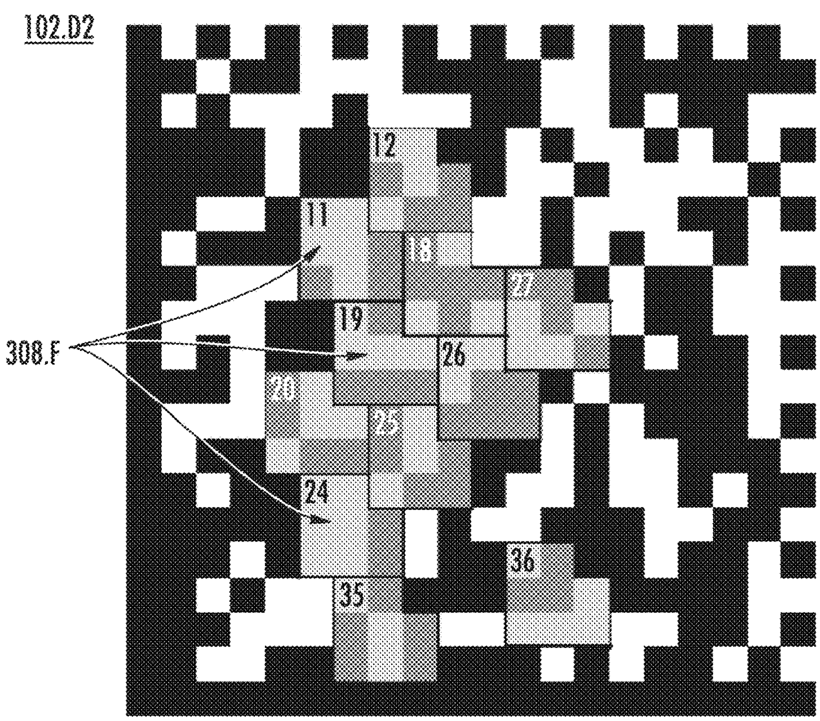
102.D2
308.F
12
11
18
27
19
26
20
25
24
36
35

FIG. 4

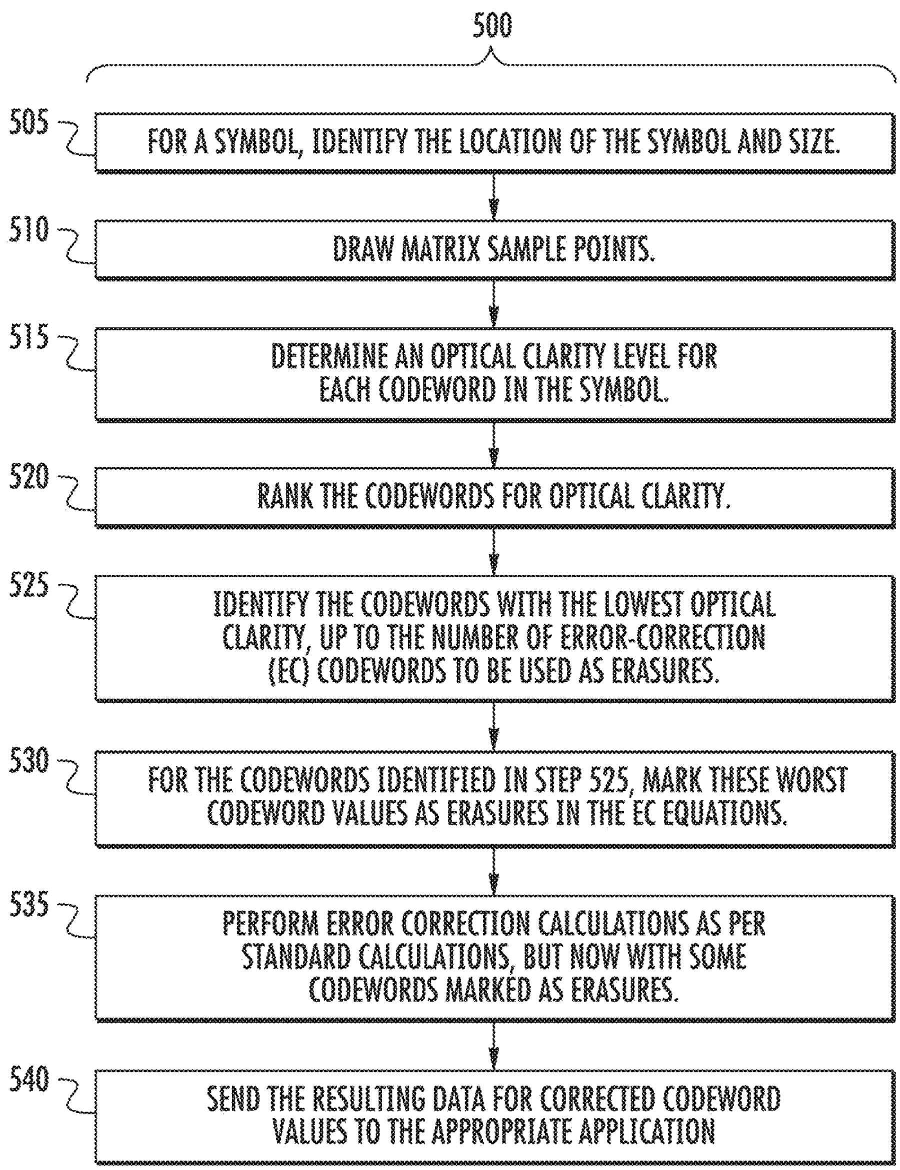
500
505
FOR A SYMBOL, IDENTIFY THE LOCATION OF THE SYMBOL AND SIZE.
510
DRAW MATRIX SAMPLE POINTS.
515
DETERMINE AN OPTICAL CLARITY LEVEL FOR EACH CODEWORD IN THE SYMBOL.
520
RANK THE CODEWORDS FOR OPTICAL CLARITY.
525
IDENTIFY THE CODEWORDS WITH THE LOWEST OPTICAL CLARITY, UP TO THE NUMBER OF ERROR-CORRECTION (EC) CODEWORDS TO BE USED AS ERASURES.
530
FOR THE CODEWORDS IDENTIFIED IN STEP 525, MARK THESE WORST CODEWORD VALUES AS ERASURES IN THE EC EQUATIONS.
535
PERFORM ERROR CORRECTION CALCULATIONS AS PER STANDARD CALCULATIONS, BUT NOW WITH SOME CODEWORDS MARKED AS ERASURES.
540
SEND THE RESULTING DATA FOR CORRECTED CODEWORD VALUES TO THE APPROPRIATE APPLICATION

FIG. 5

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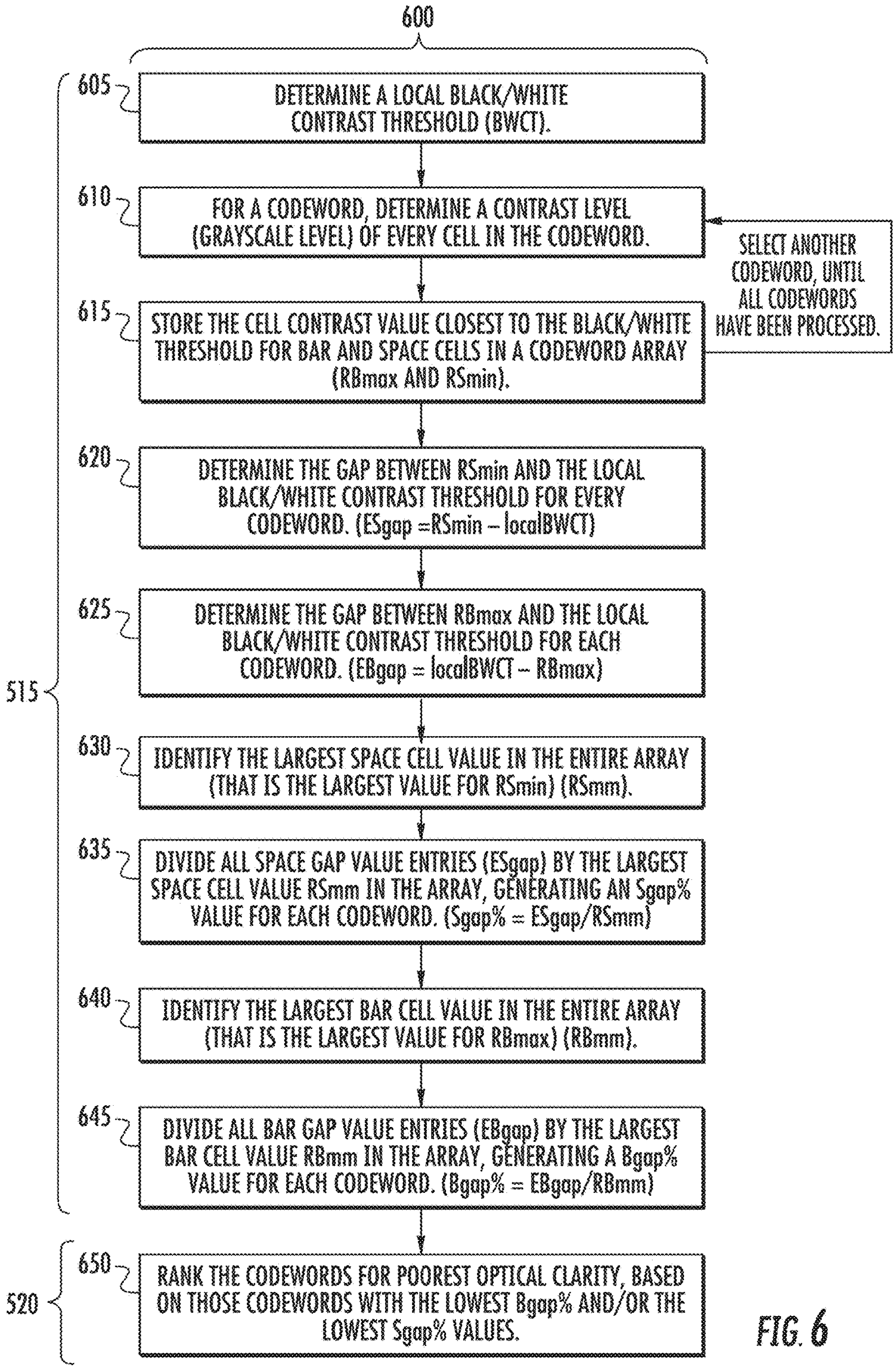
600
605
DETERMINE A LOCAL BLACK/WHITE CONTRAST THRESHOLD (BWCT).
610
FOR A CODEWORD, DETERMINE A CONTRAST LEVEL (GRAYSCALE LEVEL) OF EVERY CELL IN THE CODEWORD.
SELECT ANOTHER CODEWORD, UNTIL ALL CODEWORDS HAVE BEEN PROCESSED.
615
STORE THE CELL CONTRAST VALUE CLOSEST TO THE BLACK/WHITE THRESHOLD FOR BAR AND SPACE CELLS IN A CODEWORD ARRAY (RBmax AND RSmin).
620
DETERMINE THE GAP BETWEEN RSmin AND THE LOCAL BLACK/WHITE CONTRAST THRESHOLD FOR EVERY CODEWORD. (ESgap =RSmin – localBWCT)
625
DETERMINE THE GAP BETWEEN RBmax AND THE LOCAL BLACK/WHITE CONTRAST THRESHOLD FOR EACH CODEWORD. (EBgap = localBWCT – RBmax)
515
630
IDENTIFY THE LARGEST SPACE CELL VALUE IN THE ENTIRE ARRAY (THAT IS THE LARGEST VALUE FOR RSmin) (RSmm).
635
DIVIDE ALL SPACE GAP VALUE ENTRIES (ESgap) BY THE LARGEST SPACE CELL VALUE RSmm IN THE ARRAY, GENERATING AN Sgap% VALUE FOR EACH CODEWORD. (Sgap% = ESgap/RSmm)
640
IDENTIFY THE LARGEST BAR CELL VALUE IN THE ENTIRE ARRAY (THAT IS THE LARGEST VALUE FOR RBmax) (RBmm).
645
DIVIDE ALL BAR GAP VALUE ENTRIES (EBgap) BY THE LARGEST BAR CELL VALUE RBmm IN THE ARRAY, GENERATING A Bgap% VALUE FOR EACH CODEWORD. (Bgap% = EBgap/RBmm)
650
520
RANK THE CODEWORDS FOR POOREST OPTICAL CLARITY, BASED ON THOSE CODEWORDS WITH THE LOWEST Bgap% AND/OR THE LOWEST Sgap% VALUES.

FIG. 6

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700

702 702

CW	RSmin	RBmax	ESgap	Sgap%	EBgap	Bgap%	RANK
1	D0	58	5B	85	1D	47	
2	B8	47	43	63	2E	74	
3	B8	40	43	63	35	85	
4	AF	47	3A	54	2E	74	
5	A0	3F	2B	40	36	87	
6	DF	47	6A	99	2E	74	
7	D0	40	5B	85	35	85	
8	D8	3F	63	93	36	87	
9	DF	3F	6A	99	36	87	
10	A8	3F	33	48	36	87	
11!	7F	3F	0A	09	36	87	4
12!	88	3F	13	18	36	87	7
13	AF	40	3A	54	35	85	
14	C0	3F	4B	70	36	87	
15	BF	3F	4A	69	36	87	
16	DF	3F	6A	99	36	87	
17	C0	3F	4B	70	36	87	
18!	77	38	02	02	3D	98	2
19!	77	3F	02	02	36	87	1
20!	9F	40	2A	39	35	85	12
21	D7	3F	62	92	36	87	
22	E0	67	6B	100	0E	23	9
23	C8	40	53	78	35	85	
24!	80	3F	0B	10	36	87	6
25!	88	3F	13	18	36	87	8
26!	90	38	1B	25	3D	98	11
27!	A7	3F	32	47	36	87	XXX
28	DF	40	6A	99	35	85	
29	DF	40	6A	99	35	85	
30	D0	3F	5B	85	36	87	
31	CF	38	5A	84	3D	98	
32	BF	40	4A	69	35	85	
33	AF	38	3A	54	3D	98	
34	7F	3F	0A	09	36	87	5
35!	78	3F	03	03	36	87	3
36!	8F	3F	1A	24	36	87	10
37	CF	3F	5A	84	36	87	
38	D7	37	62	92	3E	100	
39	D0	38	5B	85	3D	98	
40	C8	3F	53	78	36	87	

FIG. 7

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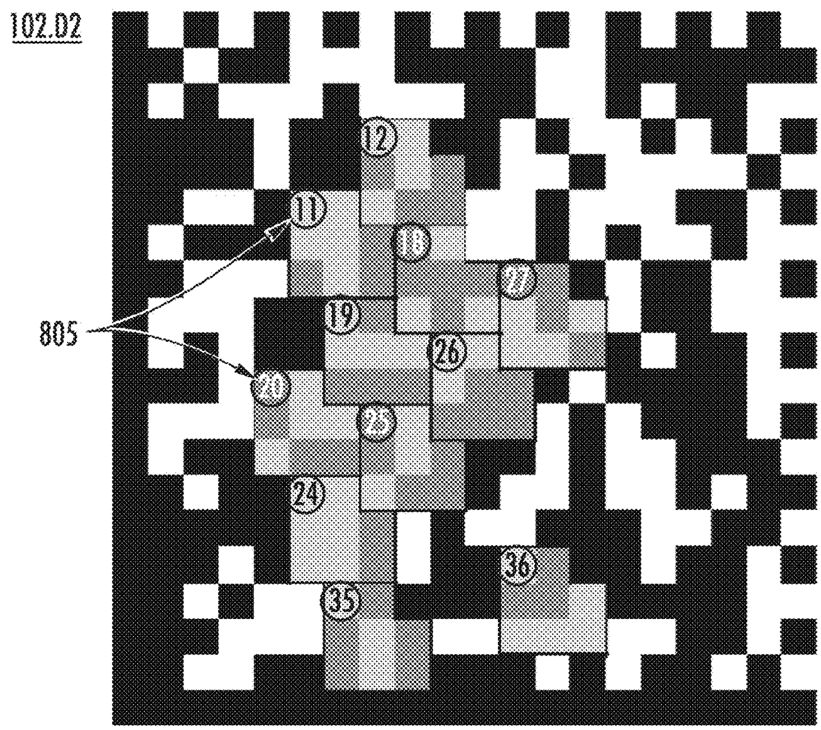
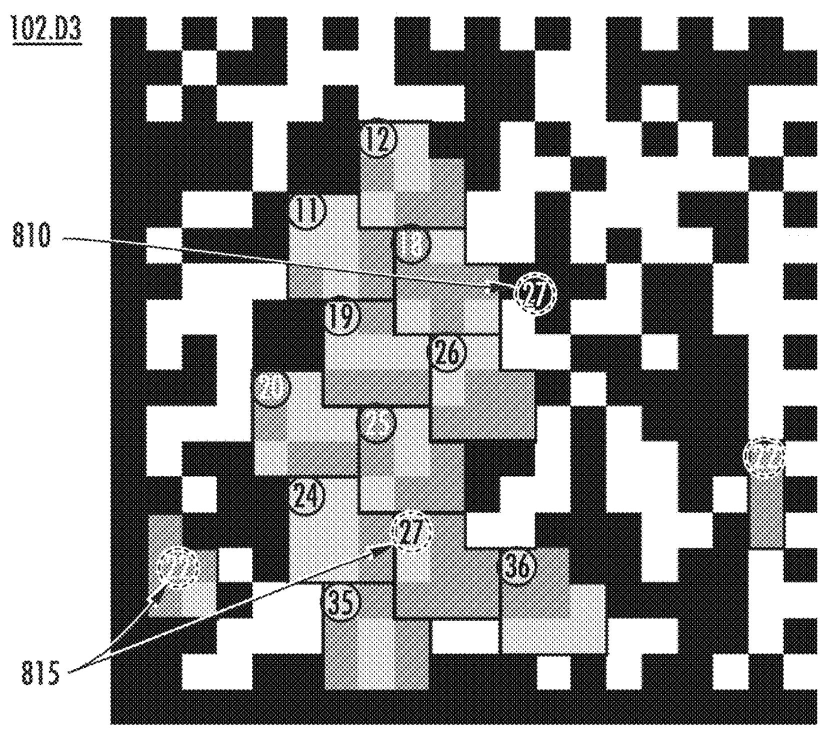


ACTUAL CODEWORDS IN ERROR AS INTERPRETED BY A SCANNER IN THE FIELD.



SAME SYMBOL, CODEWORDS-IN-ERROR AS ANALYZED BY ALGORITHM.

FIG. 8

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ENHANCED MATRIX SYMBOL ERROR CORRECTION METHOD

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of U.S. patent application Ser. No. 15/006,561 for Enhanced Matrix Symbol Error Correction Method filed Jan. 26, 2016 (and published Jul. 27, 2017 as U.S. Patent Application Publication No. 2017/0213064). Each of the foregoing patent application and patent publication is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for decoding machine-readable symbols, and more particularly, to a method and apparatus for decoding symbols requiring error correction.

BACKGROUND

Machine-readable symbols provide a means for encoding information in a compact printed form (or embossed form) which can be scanned and then interpreted by an optical-based symbol detector. Such machine readable symbols are often attached to (or impressed upon) product packaging, food products, general consumer items, machine parts, equipment, and other manufactured items for purposes of machine-based identification and tracking.

One exemplary type of machine-readable symbol is a bar code that employs a series of bars and white spaces vertically oriented along a single row. Groups of bars and spaces correspond to a codeword. The codeword is associated with an alpha-numeric symbol, one or more numeric digits, or other symbol functionality.

To facilitate encoding of greater amounts of information into a single machine-readable symbol, two-dimensional bar codes have been devised. These are also commonly referred to as stacked, matrix and/or area bar codes. Examples of such two-dimensional symbologies include Data Matrix, Code One, PDF-417, MaxiCode, QR Code, and Aztec Code. 2D matrix symbologies employ arrangements of regular polygon-shaped cells (also called elements or modules) where the center to center distance of adjacent elements is uniform. Typically, the polygon-shaped cells are squares. The specific arrangement of the cells in 2D matrix symbologies represents data characters and/or symbology functions.

As an example of a 2D matrix symbol technology, a Data Matrix code is a two-dimensional matrix barcode consisting of high-contrast "cells" (typically black and white cells) or modules arranged in either a square or rectangular pattern. The information to be encoded can be text or numeric data, or control symbols. The usual data size ranges from a few bytes up to 1556 bytes. Specific, designated, standardized groups of cells—typically eight cells—are each referred to as a "symbol character." The symbol characters have values which are referred to as "codewords." With a black cell interpreted as a 0 (zero) and a white cell interpreted as a 1 (one), an eight-cell codeword can code for numbers 0 through 255; in turn, these numeric values can be associated with alphanumeric symbols through standard codes such as ASCII, EBCDIC, or variations thereon, or other functionality.

The codewords—that is, the designated groups of cells in a symbol—have specific, standardized positions within the overall symbol. The interpretation of a symbol in a given context (for example, for a given manufacturer and/or a given product) therefore depends on the codewords within the symbol; and in particular, the interpretation depends on both: (i) the contents of each codeword (that is, the pattern of cells in each codeword), and (ii) the placement or position of each codeword in the symbol.

Typically, for sequential alphanumeric data (for example, a product identification number or a street address), each sequential data character is assigned to the symbols of a codeword in a standardized order. For example, the order may be left-to-right along the rows of the symbol, or according to a standardized diagonal pattern of placement. Because the codewords have specific, standards-specified placements within a symbol—and because no information about the placement is contained in the symbol character—the symbols may also be referred to as "matrix symbols" or "matrix symbology barcodes."

Bar code readers are employed to read the matrix symbols using a variety of optical scanning electronics and methods. Ideally, the machine-readable symbols which are scanned by a bar code reader are in perfect condition, with all of the cells of consistent, uniform size; each cell being fully filled with either total black or total white; and the contrast between black and white cells being 100%.

In real, practical application the machine-readable symbols which are scanned by a bar code reader may be imperfect. They may be smudged by external substances (grease, dirt, or other chemicals in the environment); or the surface on which the symbols were printed may be stretched, compressed, or torn; or the printing process itself may be flawed (for example, due to low ink levels in a printer, clogged printheads, etc.). The defects in actual symbols may introduce errors in the machine reading process.

To address these practical problems, error correction techniques are often used to increase reliability: even if one or more cells are damaged so as to make a codeword unreadable, the unreadable codeword can be recovered through the error-correction process, and the overall message of the symbol can still be read.

For example, machine-readable symbols based on the Data Matrix ECC 200 standard employ Reed-Solomon codes for error and erasure recovery. ECC 200 allows the routine reconstruction of the entire encoded data string when the symbol has sustained 25% damage (assuming the matrix can still be accurately located).

Under this standard, approximately half the codewords in a symbol are used directly for the data to be represented, and approximately half the codewords are used for error correction. The error-correction (EC) symbols are calculated using a mathematical tool known as the Reed-Solomon algorithm. The codewords for the symbol are the input to the Reed-Solomon algorithm, and the error-correction (EC) symbols are the output of the Reed-Solomon algorithm. The complete machine-readable symbol includes both the data codewords and the EC codewords.

For a given symbol format (such as Data Matrix, PDF-417, QR-Code, Aztec Code, and others), and for a given size of the symbol matrix, there are a fixed, designated numbers of EC codewords. To recover any one, particular damaged (unreadable) codeword, two things must be recovered: (i) the location of the damaged data codeword within the symbol, and (ii) the contents (the bit pattern) of the damaged data codeword. In turn, to recover both the location and the bit pattern for a single codeword requires two of the available EC symbols. It follows that if a machine-readable symbol has two damaged codewords, four EC codewords

are required to recover the full symbol. Generally, if a symbol has "N" damaged codewords, then 2*N EC codewords are required to recover the full symbol.

The number of EC codewords in a symbol is limited. This places a limit on the number of damaged, unreadable data codewords which can be recovered. Generally, with error correction techniques, and using present methods, the number of damaged data codewords which can be recovered is half the total number of EC codewords. For example, in a Data Matrix symbol with 16×16 cells, the total number of EC codewords is 12. This means that at most 6 damaged data codewords can be recovered. If more than 6 of the data codewords are damaged, the complete symbol may be unreadable.

However, if the location of the data codeword in error is already known, then only one EC codeword is needed to correct the error. This technique is called "erasure decoding". Unfortunately, in Matrix Code symbols generally, the location of the errors is not known.

Therefore, there exists a need for a system and method for recovering more damaged data codewords in a symbol than may be recovered based on only the error-correcting symbols by themselves. More particularly, what is needed is a system and method for determining the location of a damaged or erroneous data codeword, independent of the information stored in the EC codewords.

SUMMARY

Accordingly, in one aspect, the present invention solves the problem of not being able to use erasure decoding with matrix symbologies by evaluating the gray-level information available in the scanner and keeping track of those codewords with the least contrast difference. The decoder then utilizes erasure decoding on these least-contrast codewords. Since the location of the erroneous data codewords has been estimated via the contrast detection, only one EC codeword is required to recover the data in the damaged codeword. (And so, only one EC codeword is required to fully recover the damaged data codeword, both its location and data.)

Because only one EC codeword is required instead of two, more EC codewords remain unused and available for decoding other possible errors. This increases the total number of data codewords that can be corrected. This is particularly useful in applications where symbols get dirty (e.g. automotive assembly), damaged (e.g. supply chain), have specular components (e.g. direct part marking (DPM)) and need to be scanned over a greater range (e.g. all applications).

The algorithm of the present invention has the effect of nearly doubling the number of codewords that can be corrected in matrix symbology decodes, thereby greatly improving the performance over what is currently available.

The foregoing illustrative summary, as well as other exemplary objectives and/or advantages of the invention, and the manner in which the same are accomplished, are further explained within the following detailed description and its accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an exemplary hand-held symbol reader acquiring data from a machine-readable symbol.

FIG. **2** is an internal block diagram of an exemplary symbol reader for acquiring data from a machine-readable symbol

FIG. **3** illustrates several exemplary machine-readable 2D symbols.

FIG. **4** provides two views of an exemplary 2D symbol which is damaged.

FIG. **5** is a flow-chart of an exemplary method for optically enhanced Reed-Solomon error-correction for a 2D symbol.

FIG. **6** is a flow-chart of an exemplary method for contrast analysis for a 2D symbol as part of enhanced Reed-Solomon error correction.

FIG. **7** presents an exemplary array of codeword contrast values used for enhanced error correction by applying contrast analysis to a flawed codeword.

FIG. **8** illustrates an exemplary case-study of enhanced error correction by applying contrast analysis to a flawed codeword.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various embodiments. However, one skilled in the art will understand that the invention may be practiced without these details. In other instances, well-known structures associated with imagers, scanners, and/or other devices operable to read machine-readable symbols have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments.

Unless the context requires otherwise, throughout the specification and claims which follow, the word "comprise" and variations thereof, such as, "comprises" and "comprising" are to be construed in an open sense, that is as "including, but not limited to."

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

The headings provided herein are for convenience only and do not interpret the scope or meaning of the claimed invention.

Symbol Reader

The present system and method embrace devices designed to read machine-readable symbols.

In an exemplary embodiment, such a device may be a hand-held scanner. FIG. **1** is a perspective view of an exemplary hand-held symbol reader **100** acquiring data from a machine-readable symbol **102**.

The machine-readable symbol **102** is affixed to a package **104** or the like such that the user points the hand-held symbol reader **100** towards the machine-readable symbol **102**. The symbol reader **100** may be a line scanner operable to emit and sweep a narrow beam of electromagnetic energy across a field-of-view **106** over two-dimensional (2D) machine-readable symbol **102**. In other embodiments, an aperture means, mirror, lens or the like is adjusted to sweep across a symbol line to receive returning electromagnetic energy from a relatively small portion (e.g., cell) of the machine-readable symbol, which is detected by an optical detector system.

In yet other embodiments, a 2D array symbol reader acquires a captured image of the machine-readable symbol

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(and a suitable region of quiet area around the machine-readable symbol). For the present system and method, which relies upon a contrast analysis of the cells within the symbol **102**, the acquisition of a captured image of the symbol may be a preferred method of operation for the symbol reader **100**. Suitable image processing hardware **235** and software running on processors **242**, **244** are used to deconstruct the capture image to determine the data bits represented by the cells, and to perform the contrast analysis of the present system and method (see FIG. **2** below).

The machine-readable symbol reader **100** is illustrated as having a housing **108**, a display **110**, a keypad **112**, and an actuator device **114**. Actuator device **114** may be a trigger, button, or other suitable actuator operable by the user to initiate the symbol reading process.

The machine-readable symbol **102** shown in the figure is intended to be generic and, thus, is illustrative of the various types and formats of machine-readable symbols. For example, some machine-readable symbols may consist of a single row of codewords (e.g., barcode). Other types of machine-readable symbols (e.g., matrix or area code) may be configured in other shapes, such as circles, hexagons, rectangles, squares and the like. It is intended that many various types and formats of machine-readable symbologies be included within the scope of the present system and method.

Symbol Reader Internal Block Diagram

An internal block diagram of an exemplary symbol reader **100** of a type which may implement the present system and method is shown in FIG. **2**.

In one embodiment of the present system and method, the symbol reader **100** may be an optical reader. Optical reader **100** may include an illumination assembly **220** for illuminating a target object T, such as a 1D or 2D bar code symbol **102**, and an imaging assembly **230** for receiving an image of object T and generating an electrical output signal indicative of the data which is optically encoded therein. Illumination assembly **220** may, for example, include an illumination source assembly **222**, such as one or more LEDs, together with an illuminating optics assembly **224**, such as one or more reflectors, for directing light from light source **222** in the direction of target object T. Illumination assembly **220** may be eliminated if ambient light levels are certain to be high enough to allow high quality images of object T to be taken.

In an embodiment, imaging assembly **230** may include an image sensor **232**, such as a 2D CCD or CMOS solid state image sensor, together with an imaging optics assembly **234** for receiving and focusing an image of object T onto image sensor **32**. The array-based imaging assembly shown in FIG. **2** may be replaced by a laser scanning based imaging assembly comprising a laser source, a scanning mechanism, emit and receive optics, a photodetector and accompanying signal processing circuitry. The field of view of the imaging assembly **230** will depend on the application. In general, the field of view should be large enough so that the imaging assembly can capture a bit map representation of a scene including an image data reading region at close reading range.

In an embodiment of the present system and method, exemplary symbol reader **100** of FIG. **2** also includes programmable controller **240** which may comprise an integrated circuit microprocessor **242** and an application specific integrated circuit (ASIC) **244**. Processor **242** and ASIC **244** are both programmable control devices which are able to receive, output and process data in accordance with a stored program stored in either or both of a read/write random access memory (RAM) **245** and an erasable read only memory (EROM) **246**. Processor **242** and ASIC **244** are also both connected to a common bus **248** through which program data and working data, including address data, may be received and transmitted in either direction to any circuitry that is also connected thereto. Processor **242** and ASIC **244** may differ from one another, however, in how they are made and how they are used.

In one embodiment, processor **242** may be a general purpose, off-the-shelf VLSI integrated circuit microprocessor which has overall control of the circuitry of FIG. **2**, but which devotes most of its time to decoding image data stored in RAM **245** in accordance with program data stored in EROM **246**. Processor **244**, on the other hand, may be a special purpose VLSI integrated circuit, such as a programmable logic or gate array, which is programmed to devote its time to functions other than decoding image data, and thereby relieve processor **242** from the burden of performing these functions.

In an alternative embodiment, special purpose processor **244** may be eliminated entirely if general purpose processor **242** is fast enough and powerful enough to perform all of the functions contemplated by the present system and method. It will, therefore, be understood that neither the number of processors used, nor the division of labor there between, is of any fundamental significance for purposes of the present system and method.

In an embodiment, exemplary symbol reader **100** includes a signal processor **235** and an analog-to-digital (A/D) chip **236**. These chips together take the raw data from image sensor **232** and convert the data to digital format, which in an exemplary embodiment may be a gray-level digital format, for further processing by programmable controller **240**.

In an embodiment, the system and method of the present invention employs algorithms stored in EROM **246** which enable the programmable controller **240** to analyze the image data from signal processor **235** and A/D **236**. In an embodiment, and as described further below, this image analysis may include analyzing gray-level information (contrast levels) in the image data. In an embodiment, and in part based on the contrast level analysis, programmable controller **240** may then implement an improved system and method of error correction for matrix symbols by relying on optical contrast-level analysis, as also described further below.

Exemplary symbol reader **100** may also include input/output (I/O) circuitry **237**, for example to support the use of the keyboard **112** and trigger **114**. Symbol reader **100** may also include output/display circuitry **238** to support display **110**.

Exemplary Symbols

FIG. **3** illustrates several exemplary machine-readable 2D symbols **102** labeled **102.1** and **102.2**.

Symbol **102.1** is an exemplary machine-readable symbol encoded according to the Data Matrix barcode (ECC 200) standard. The symbol **102.1**, which is a 24×24 array, has two solid black borders **302** forming an "L-shape" which are the finder pattern, enabling the symbol reader to determine the location and orientation of the 2D symbol. The symbol also has two opposing borders of alternating dark and light cells which form a "timing pattern" **304** which help the symbol reader identify the size (the number of rows and columns) of the symbol.

Interior to the finder pattern **302** and timing pattern **304** are rows and columns of interior cells **306** which encode information. As may be evident from the figure, an ideal

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machine-readable symbol has a very high contrast level between the first color dark cells and the second color light cells, in many cases achieved by employing clearly printed, unobscured cells which are either all black or all white.

Symbol **102**.**2** is an exemplary 16×16 machine-readable symbol encoded according to the Data Matrix barcode (ECC 200) standard. In symbol **102**.**2**, and for purposes of illustration only, the interior black data cells are omitted, and boundaries between the interior cells **306** are suggested by shaded, dotted lines which are not normally present in actual printed data matrix symbols.

Also, not normally present in actual printed symbols, but included here for purposes of illustration, are solid borders which indicate the boundaries of the codewords **308** formed by the interior cells **306**. In an embodiment, each codeword **308** is composed of eight cells representing a single byte of data. It will be seen that there are several types of codewords, including data codewords **308**.**1** which encode the actual data to be represented by the symbol; error-correcting (EC) codewords **308**.**2** which are generated from the data codewords according to the Reed-Solomon algorithm; and padding codewords **308**.**3**.

The figure also identifies one exemplary bar (black) cell **306**.B and one exemplary space (white) cell **306**.S.

The illustration here of machine-readable symbols based on the Data Matrix barcode standard, as well as the size, shape, and data contents illustrated, are exemplary only and should not be construed as limiting. The present system and method are applicable to a wide variety of 2D matrix barcodes according to a variety of known standards, as well as being applicable to other 2D machine-readable symbols which may be envisioned in the future.

Symbol Errors

As discussed above, the data content of symbols **102** is stored or presented in the form of cells **306** of contrasting colors within codewords **308**. In an embodiment of the present system and method, the light cells (typically white) represent ones (1's) and the dark cells (typically black) represent zeros (0's). In an alternative embodiment, a light cell represents zero (0) and the dark cells represent (1). In alternative embodiments, other colors or levels of shading may be employed. As a general matter, however, for the coding to be effective the symbol reader **100** must be readily able to distinguish the dark cells from the light cells. Also, the data is stored not only in terms of the cells **306** per se, but also in terms of the positions of the cells **306** within the codewords **308**, and the positions of each codeword **308** within the symbol **102**.

If a symbol **102** is damaged, there may be insufficient contrast between light cells and dark cells for the symbol reader **100** to reliable distinguish the cells. Similarly, damage to the symbol may render it difficult for the symbol reader to identify the location or boundaries of cells **306** and codewords **308**. In other cases, damage to cells **306** can cause a change from black to white or vice-versa. This in turn calls upon the error-correction methods, such as Reed-Solomon, already discussed above. The present system and method are intended to augment Reed-Solomon and similar error-correction methods with information based on contrast analysis.

FIG. **4** provides two views **102**.D1, **102**.D2 of an exemplary symbol which is damaged, so that the original high-contrast has been lost while the symbol **102** is in use in the field.

In the first view, the damaged symbol **102**.D1 shown in the figure was photographed in a real-world automotive manufacturing plant. It is apparent that there is a dark vertical scuff mark **402** which is approximately down the middle of the symbol **102**.D1. The scuffing is sufficiently dark that, when read with a standard symbol reader **100**, the reader **100** mistakes many individual cells **306** for black when (as printed, and without damage or scuffing) they are white cells. This in turns causes codeword errors. This symbol **102**.D1 will not read with current scanners.

The actual value of the codewords in symbol **102**.D1 is listed here (codewords before the colon are data codewords, those after the colon are error-correction codewords):

237 151 230 204 27 207 144 165 112 27 13 43 222 60 125 34 137 186 71 163 223 254:96 9 171 31 209 21 131 100 111 146 225 95 109 112 182 218 118 203

The values for the codewords determined by a symbol reader **100** are shown here, with the incorrect codewords underlined:

237 151 230 204 27 207 144 165 112 27 <u>173</u> <u>111</u> 222 60 125 34 137 <u>191</u> <u>127</u> <u>235</u> 223 254:96 <u>25</u> <u>175</u> <u>191</u> <u>208</u> 21 131 100 111 146 225 95 <u>111</u> <u>116</u> 182 218 118 203

As is apparent in the image of symbol **102**.D1, throughout the smudged region **402** the contrast between many individual cells is small, and is close to the threshold level between black and white. Compare for example a cluster of low contrast cells **404** within the smudged region **402** with a non-damaged, machine-readable high contrast region **406**.

In the second view, the damaged symbol **102**.D2 is illustrated as it was interpreted by an actual scanner **100** in the field. As shown by the codewords with shaded cells **306** in the illustration, there were eleven codewords **308** which provided flawed readings from the scanner **100**, and may be described as flawed codewords **308**.F.

Erasure vs. Error:

By way of terminology, it is noted here that if the position of an erroneous codeword is known, but the data is not known (or is ambiguous), the codeword is referred to as an "erasure." If the data of an erroneous codeword is unknown and the position of the codeword is also unknown, the codeword is referred to as an "error."

Reed-Solomon Error Correction

In an embodiment, the present system and method includes application of error-correcting codes and analyses, augmented with optical analysis of a machine-readable symbol **102**, to detect and correct errors in the machine-readable symbol **102**. Various mathematical methods of error correction are well-known in the art, and a detailed description is beyond the scope of this document. However, review of a few basic elements of an exemplary error-correction method may aid in the understanding of the present system and method.

All standardized 2D matrix symbologies utilize the Reed-Solomon methodology. In Reed-Solomon codes, a set of data elements, such as bytes of data, may be redundantly encoded in a second set of error-correcting elements (also typically in byte form), which for present purposes can be referred to as EC codewords **308**.**2**. The error-correcting codewords are transmitted or presented along with the principle data elements, enabling reconstruction of damaged data elements.

Methods of constructing the Reed-Solomon EC codewords (based on a given, particular data set) are outside the scope of this document. It suffices for present purposes to understand that Reed-Solomon-derived EC codewords **308**.**2** can be calculated, and the resulting EC codewords are included as part of 2D matrix symbols, as already described above.

There are a variety of methods of decoding a message with Reed-Solomon error correction. In one exemplary

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method, the values of the data codewords **308.1** of a symbol **102** are viewed as the coefficients of a polynomial s(x) that is subject to certain constraints (not discussed here):

$$S(x) = \sum_{i=0}^{n-1} c_i x^i$$

It will be noted that not only the values of the data codewords **308.1** matter, but also their order. The ordinal placement of the codewords (1^{st}, 2^{nd}, 3^{rd}, etc.) in the polynomial maps to the physical ordering of the data codewords **308.1** in the machine-readable symbol **102**.

If the machine-readable symbol **102** is damaged or corrupted, this may result in data codewords **308.1** which are incorrect. The erroneous data can be understood as a received polynomial r(x):

$$r(x) = s(x) + e(x)$$

$$e(x) = \sum_{i=0}^{n-1} e_i x^i$$

where e_i is the coefficient for the i^{th} power of x. Coefficient e_i will be zero if there is no error at that power of x (and so no error for the corresponding i^{th} data codeword **308.1** in the symbol **102**); while the coefficient e_i will be nonzero if there is an error. If there are ν errors at distinct powers i_k of x, then:

$$e(x) = \sum_{k=1}^{N} (\text{e\_i}_k)(x \wedge i_k)$$

The goal of the decoder is to find the number of errors (ν), the positions of the errors (i_k), and the error values at those positions (e_i_k). From those, e(x) can be calculated, and then e(x) can be subtracted from the received r(x) to get the original message s(x).

There are various algorithms which can be employed, as part of the Reed-Solomon scheme, to identify the error positions (i_k) and the error values at those positions (e_i_k), based solely on the received data codewords **308.1** and the received EC codewords **308.2**. The processes involved, however, are generally a two-stage processes, where:

Stage (I) Error Locations: The first calculation stage entails identifying the location of the errors. This entails first calculating an error-locator polynomial Λ, and based on Λ, calculating the non-zero error positions i_k. This stage also determines the number of errors (ν). This first stage calculation inevitably requires the use of some of the EC codewords **308.2** in the symbol **102**.

Stage (II) Corrected Values:

Employing the location errors i_k as calculated in stage (i), the second calculation stage identifies the correct values (e_i_k) associated with each error location.

It will be seen then that in the prior art, correcting errors is a two-stage process, where identifying error locations generally precedes, and is an input to, identifying the corrected data at each location. It is a goal of the present system and method to either reduce or possibly eliminate the calculations of stage (I), by using analyses apart from Reed-Solomon error correction to determine identify or mark the erroneous data codewords **308.1**.

Persons skilled in the art will recognize that the non-zero error positions i_k calculated via the alternative methods (discussed further below) can be input directly into stage (II), thereby enabling the calculations of the correct data values in stage (II).

Importantly, in the mathematics of standard Reed-Solomon error correction, errors (both location and data unknown) requires the use of two error correcting code words to repair a damaged codeword. If, on the other hand, knowledge of the location of the error exists, then the error is considered an erasure, and only one error correction codeword is required to repair the erased codeword.

Stated another way: Normally, error-correction in 2D matrix symbologies is used to correct codewords which are errors, meaning that both the location and contents of the codeword are unknown. The goal of the present system and method is to independently flag errors so that they are instead treated as erasures, for which the location is known, thereby requiring only one EC codeword for correction.

Optical Clarity and Optical Ambiguity, Decoding Disadvantage, and Reed-Solomon Error Correction

As discussed above, Reed-Solomon error correction requires the use of two EC codewords **308.2** to correctly recover both the location and the data contents of a single data codeword **308.1** which is flawed. However, the present system and method aims to enable the identification (at least provisionally) of the locations of the flawed or damaged codewords **308**.F—and to make such identification independently of the EC codewords **308.2** in the symbol **102**. Such alternative means of locating the data codewords **308.1** which are flawed supplements the data in the EC codewords **308.2**; as a result, only a single EC codeword **308.2** is required to identify the data in a data codeword **308.1** Flawed codewords **308**.F may also be referred to as codewords which have a “decoding disadvantage.”

To identify the locations of the codewords with a decoding disadvantage, independent of the error-correcting information within the symbol **102** itself, the present system and method identifies those codewords **308** in the symbol **102** which have a low level of optical clarity, or equivalently, a high level of optical ambiguity. By “optical clarity” is meant any codeword **308** which, as presented to the reader **100**, is sufficiently clear and distinct (e.g., has high optical contrast) to be read very reliably by the symbol reader’s optical system **230**, **235**. If a codeword **308** is not optically clear—for example, due to poor printing, smudging or marking in the field, ripping or tearing, or other causes—then the codeword is deemed optically ambiguous; there is a significant probability that the data for an optically ambiguous codeword, as determined by a reader **100**, will not match the intended data of the same codeword.

FIG. **5** presents a flow-chart of an exemplary method **500** for optically enhanced Reed-Solomon error-correction for a symbol **102**. The steps of exemplary method **500** are generally performed via the processor(s) **240**, memory **245**, and other components of the symbol reader **100**.

In step **505**, the symbol reader **100** identifies the location of the symbol **102** and the appropriate parameters such as the size. For example, for a DataMatrix symbol, the reader **100** finds the “L-shape” **302** and finds the clock track **304** to identify the number of rows and columns in the symbol. The L-shape **302** and clock track **304** help the reader **100** determine the symbol’s tilt and orientation, and provide reference points from which to decode the matrix of data cells.

In step **510**, the symbol reader **100** creates a matrix or array of sample points (pixels), indicating the reflectances

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(bright or dark) of points within the symbol **102**. These sample points are used to determine reflectance of cells **306** within the symbol. A single cell **306** may have multiple sample points measured, and together these may be used (for example, averaged) to determine the reflectance of each cell **306**.

As discussed above, the symbol **102** is composed of codewords **308** with standardized positions, that is, which are made up of standardized clusters of cells **306** with designated positions within the symbol matrix **102**.

In step **515**, the method **500** determines a level of optical clarity for each codeword **308**. A high level of optical clarity, which is desirable, means the codeword's cells are distinctive and that the data value of the codeword can be read with a high probability of accuracy.

A low level of optical clarity—or equivalently, a high level of optical ambiguity—may result from physical damage to a symbol, or from dirt or grease marking the symbol, or other causes as discussed above. Low optical clarity, or high optical ambiguity, means that the codeword's cells are not distinctive and the codeword has a decoding disadvantage. The low level of optical clarity therefore means that the data value of the codeword can be ascertained only with a suboptimal degree of reliability.

Optical clarity/ambiguity may be determined in a variety of ways. In one embodiment of the present system and method, discussed in detail below, the optical clarity/ambiguity is determined based on an analysis of the contrast level between cells **306** within each codeword **308**. Codewords **306** which exhibit the lowest internal contrast levels may be marked as optically ambiguous.

In an alternative embodiment, optical clarity/ambiguity may be determined based on analysis of the degree to which a codeword **308** is in-focus or not in-focus. In an alternative embodiment, optical clarity/ambiguity may be determined based on analysis of the definition or lack of definition of lines separating the dark cells **306** from light cells **306**.

In an alternative embodiment, optical clarity/ambiguity may be determined based on a degree to which the horizontal and vertical lines of the codewords **308** are parallel to, or are not parallel to, the border-L shape. Other methods of assessing optical clarity of a codeword **308** may be envisioned as well, and fall within the scope and spirit of the present system and method.

In step **520**, exemplary method **500** ranks the codewords **308** according to optical clarity, for example from highest to lowest in optical clarity. In step **525**, method **500** identifies the lowest ranked codewords (those which are most optically ambiguous), up to the number of codewords **308** to be used as erasures.

In steps **530** and **535**, the lowest-ranked codewords **308** identified in step **525**—that is, the codewords with the highest optical ambiguity—are marked as erasures in the error-correction equations, and the Reed-Solomon error-correction equations are then executed. Steps **530** and **535** thereby reduce or eliminate the calculations discussed above for a phase (I) of the Reed-Solomon error correction process, and thereby also reduce or eliminate the use of EC codewords **308.2** to identify the locations of flawed codewords **308**.F.

Gray-Scale Contrast Analysis Algorithm

In one embodiment, the present system and method identifies codewords **308** with high optical ambiguity (low optical clarity) via contrast analysis of the codewords within the symbol **102**.

The present system and method employ a "matrix-cell contrast analysis algorithm," "gray-scale contrast analysis algorithm," or simply "contrast analysis algorithm" (CAA) for short. The contrast analysis algorithm of the present system and method determines the actual gray level of each cell **306** in the symbol **102**. The CAA also identifies the black/white contrast threshold for the symbol **102**. The black/white contrast threshold is the brightness level above which a cell **306** is considered to be white, and below which a cell is considered to be black. The algorithm then determines the difference between the contrast level of each cell **306** and the black/white threshold. If the differential is comparatively low for one or more cells **306** in a particular codeword **308**, the codeword **306** may have a decoding disadvantage.

More generally, the CAA may identify a light/dark threshold level, which is a brightness level above which a cell **306** is considered to be of a first, lighter color (for example, white); and below which a cell is considered to be of a second, darker color (for example, black).

A scanner **100** will conventionally store, in memory **245**, the "color" of each cell **306**, for example, a red-green-blue (RGB) value or a hue-saturation-brightness (HSB) value. The present system and method will also store, in the memory (**245**) of the scanner **100**, an actual, measured gray-scale level for each cell **306**.

FIG. **6** presents a flow-chart of an exemplary method **600** for contrast analysis according to the present system and method. Steps **605** through **645** of exemplary method **600** collectively may be considered to be one exemplary embodiments of step **515** of method **500**, already discussed above. (Step **515** determines an optical clarity for each codeword **308** in the symbol **102**.) Step **650** of exemplary method **600** may be considered to be one exemplary embodiment of step **520** of method **500**, that is, ranking the codewords for optical clarity.

Where exemplary method **500** was directed to generally determining and ranking codewords **308** by optical clarity, the exemplary method **600** particularly employs an exemplary approach to contrast analysis in order to determine and rank optical clarity. The steps of exemplary method **600** are generally performed via the processor(s) **240**, memory **245**, and other components of the symbol reader **100**.

In step **605**, the symbol reader **100** determines a local black/white contrast threshold (BWCT). The black/white contrast threshold (BWCT), as described above, is a reflectance level above which a cell **306** is considered white, and below which a cell **306** is considered black. This is typically determined by (i) identifying the reflectance of all the cells **306** in the symbol; (ii) identifying the highest reflectance value and the lowest reflectance value; and (iii) identifying a middle-value, such as the mean or the median, and using the middle-value as the BWCT. The present system and method refine this by employing a local BWCT for each cell **306**. In an exemplary embodiment, a local BWCT for a given cell **306** may be determined by considering only those other cells local to the given cell **306**, and then identifying the mean or median reflectance among those cells. In an embodiment, the number of local cells used to determine the local BWCT may be twenty (20). In an alternative embodiment the number of local cells used to determine the BWCT for a given cell may be higher or lower than twenty (20).

In step **610**, the method **600** selects a particular codeword **308**, (as specified in the appropriate standards for the size and shape of the symbol **102**), and identifies the contrast level (the grayscale level) of each cell in the codeword.

In step **615**, the method **600** determines, for the particular codeword at hand, a bar cell (**306**.B) with a contrast value closest to the BWCT; and a space cell (**306**.S) with a contrast

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value closest to the BWCT; and then stores these two cell contrast values in a codeword contrast values array in memory (see FIG. **7** below for an example). The contrast values may be labeled as RSmin for the space cell (**306**.S) closest to the BWCT, and RBmax for the bar cell (**306**.B) closest to the BWCT. An equivalent phrasing: RSmin is the smallest space cell reflectance (darkest), and RBmax is the largest bar cell reflectance (lightest).

Steps **610** and **615** are repeated for all codewords **308** in the symbol **102**. This results in a listing of RSmin and RBmax for each codeword **308** in the symbol.

In step **620**, the method **600** determines the erasure gap for spaces between RSmin and the local black/white contrast threshold for each codeword. (ESgap=RSmin−localBWCT)

In step **625**, the method **600** determines the erasure gap for bars between RBmax and the local black/white contrast threshold for each codeword. (EBgap=localBWCT−RBmax)

In step **630**, the method **600** identifies the largest space cell value in the entire array, that is the largest value for RSmin. This value, which may be labeled as RSmm, is used for normalization in the following step.

In step **635**, the method **600** divides all space gap value entries (ESgap) by the largest space cell ("white cell") value in the array, RSmm, generating an Sgap % value for each codeword. (Sgap %=ESgap/RSmm)

In step **640**, the method **600** identifies the largest bar cell ("black cell") value in the entire array, that is the largest value for RBmin. This value, which may be labeled as RBmm, is used for normalization in the following step.

In step **645**, the method **600** divides all bar gap value entries (EBgap) by the largest bar cell value in the array, RBmm, generating a Bgap % value for each codeword. (Bgap %=EBgap/RBmm)

Sgap % and Bgap %, then, are the percentage relative closeness of the deviant cell to the black/white contrast threshold. These percentage values, Sgap % and Bgap %, may also be referred to as the minimum interior contrast levels **702** for each cell **306**. The minimum interior contrast levels **702** are a measure of the optical clarity of the codewords **308** in the symbol **102**. Specifically: Those codewords **308** with the lowest values for Sgap % and/or the lowest values for Bgap % have the highest optical ambiguity (and therefore the least or worst optical clarity).

As noted above, the preceding steps **605** through **645** of method **600** may collectively be considered to be one exemplary embodiment of step **515** of method **500**, already discussed above, that is, determining an optical clarity for each codeword **308** in the symbol **102**.

In step **650**, and based on the Sgap % and Bgap % values determined in steps **635** and **645**, the method **600** ranks the lowest gap percent values up to the number of error correction codewords to be used as erasures. Step **650** of exemplary method **600** may be considered to be one exemplary embodiment of step **520** of method **500**, that is, ranking the codewords for optical clarity/ambiguity.

These lowest ranked, least clear codewords are the codewords with the lowest optical clarity (or highest ambiguity), which are then used as erasures in the Reed-Solomon equations (step **530** of method **500**).

Sample Applications

FIG. **7** presents an exemplary codeword contrast values array **700** of the kind which may be constructed according to exemplary method **600**, above. The array contains actual codeword measurements for the symbol image **102**.D1/**102**.D2 of FIG. **4**, above. In array **700**, CW is the codeword number; and, as per discussion above:

RSmin is the smallest (darkest) space cell reflectance for each codeword **308**;

RBmax is the largest (lightest) bar cell reflectance for each codeword **308**;

ESgap is the erasure space gap calculated as RSmin minus the threshold (75hex in this case);

EBgap is the threshold minus RBmax for the bar cells;

Sgap % and Bgap % are the relative closeness of the deviant cell to the black/white threshold in percent, also referred to as the minimum interior contrast levels **702**; and

Rank is a listing of the worst **12** codewords (those with the smallest gap percentage) in the symbol **102**.

FIG. **8** illustrates an exemplary case-analysis demonstrating how poor cell contrast can identify a majority of flawed codewords **308**.F. The damaged symbols shown in the figure are the same as the damaged symbol pictured and illustrated in FIG. **4**, above. In FIG. **8**, numbered codeword locations **805** are identified (by a standardized number scheme) for those codewords which are flowed or damaged.

102.D2, reproduced here from FIG. **4** for convenience, is the damaged symbol as it was interpreted by an actual scanner **100** in the field.

Symbol **102**.D3 is the same symbol as it was interpreted according the exemplary contrast analysis algorithms discussed above in conjunction with FIG. **5** and FIG. **6**.

As can be seen in FIG. **8**, there are two codewords **815** which were assessed as being in error by the present system and method, but which were actually read correctly by the scanner **100**. Of the latter codewords, one was in the damaged region **402** (codeword **27**) and another was a codeword where there is a scratch through the dark cell, making it lighter (codeword **22**).

As can also be seen from FIG. **8**, there is one codeword **810** which was actually read in error by the scanner **100**, but was not flagged by the gray-scale contrast analysis algorithm of the present system and method.

All the remaining, identified codewords **308** (a total of ten) which were flagged as being in error based on contrast analysis are codewords which were, in fact, read in error by the scanner **100**.

The codeword that the analysis missed (codeword **27**) is easily decoded using the 6 error correction codewords still remaining. This is an example of a symbol that was far from being decodable using standard decoding methods, yet using a gray-scale contrast analysis algorithm, the symbol can sustain this and slightly more damage and still be decodable.

FURTHER APPLICATIONS

The example shown (in FIGS. **4** and **8**) clearly benefits from the gray-scale contrast analysis decoding since the damage to the symbol **102**.D1/**102**.D2 is contrast based. However, the present system and method will also work with other types of damage such as matrix distortion, uniform dark or light damage and for DPM cell variation. When these types of distortion are present, there will be many sample points that rest on cell boundaries which will be recorded as reduced contrast values. As long as the matrix distortion (such as wrinkling) is localized or the dark/light damage is less than approximately one-third of the symbol, the present system and method will substantially improve decoding rates on all types of problem symbols **102**.D.

SUMMARY

Improved matrix symbology decode performance is possible when there is some knowledge of potentially damaged

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codewords **308**. One means of achieving improved decode performance is by measuring the gray-level contrast variation of every codeword, and marking those with contrast values that are closest to the black/white threshold as erasures. Using gray-level information and using erasure correction in matrix symbologies will allow successful decoding far into a damage region where current product decoding fails.

To supplement the present disclosure, this application incorporates entirely by reference the following patents, patent application publications, and patent applications:

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8,457,013; 8,459,557;
8,469,272; 8,474,712;
8,479,992; 8,490,877;
8,517,271; 8,523,076;
8,528,818; 8,544,737;
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8,556,176; 8,556,177;
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8,596,539; 8,596,542;
8,596,543; 8,599,271;
8,599,957; 8,600,158;
8,600,167; 8,602,309;
8,608,053; 8,608,071;
8,611,309; 8,615,487;
8,616,454; 8,621,123;
8,622,303; 8,628,013;
8,628,015; 8,628,016;
8,629,926; 8,630,491;
8,635,309; 8,636,200;
8,636,212; 8,636,215;
8,636,224; 8,638,806;
8,640,958; 8,640,960;
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8,757,495; 8,760,563;
8,763,909; 8,777,108;
8,777,109; 8,779,898;
8,781,520; 8,783,573;
8,789,757; 8,789,758;
8,789,759; 8,794,520;
8,794,522; 8,794,525;
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8,820,630; 8,822,848;
8,824,692; 8,824,696;
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8,903,172; 8,908,995;
8,910,870; 8,910,875;
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U.S. Patent Application Publication No. 2015/0040378;
U.S. Patent Application Publication No. 2015/0048168;
U.S. Patent Application Publication No. 2015/0049347;
U.S. Patent Application Publication No. 2015/0051992;
U.S. Patent Application Publication No. 2015/0053766;
U.S. Patent Application Publication No. 2015/0053768;
U.S. Patent Application Publication No. 2015/0053769;
U.S. Patent Application Publication No. 2015/0060544;
U.S. Patent Application Publication No. 2015/0062366;
U.S. Patent Application Publication No. 2015/0063215;
U.S. Patent Application Publication No. 2015/0063676;
U.S. Patent Application Publication No. 2015/0069130;
U.S. Patent Application Publication No. 2015/0071819;
U.S. Patent Application Publication No. 2015/0083800;
U.S. Patent Application Publication No. 2015/0086114;
U.S. Patent Application Publication No. 2015/0088522;
U.S. Patent Application Publication No. 2015/0096872;
U.S. Patent Application Publication No. 2015/0099557;
U.S. Patent Application Publication No. 2015/0100196;
U.S. Patent Application Publication No. 2015/0102109;
U.S. Patent Application Publication No. 2015/0115035;
U.S. Patent Application Publication No. 2015/0127791;
U.S. Patent Application Publication No. 2015/0128116;
U.S. Patent Application Publication No. 2015/0129659;
U.S. Patent Application Publication No. 2015/0133047;
U.S. Patent Application Publication No. 2015/0134470;
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U.S. Patent Application Publication No. 2015/0136854;
U.S. Patent Application Publication No. 2015/0142492;
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U.S. Patent Application Publication No. 2015/0144698;
U.S. Patent Application Publication No. 2015/0144701;
U.S. Patent Application Publication No. 2015/0149946;
U.S. Patent Application Publication No. 2015/0161429;
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In the specification and/or figures, typical embodiments of the invention have been disclosed. The present invention is not limited to such exemplary embodiments. The use of the term "and/or" includes any and all combinations of one or more of the associated listed items. The figures are schematic representations and so are not necessarily drawn to scale. Unless otherwise noted, specific terms have been used in a generic and descriptive sense and not for purposes of limitation.

The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flow charts, schematics, exemplary data structures, and examples. Insofar as such block diagrams, flow charts, schematics, exemplary data structures, and examples contain one or more functions and/or operations, it will be understood by those skilled in the art that each function and/or operation within such block diagrams, flowcharts, schematics, exemplary data structures, or examples

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can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof.

In one embodiment, the present subject matter may be implemented via Application Specific Integrated Circuits (ASICs). However, those skilled in the art will recognize that the embodiments disclosed herein, in whole or in part, can be equivalently implemented in standard integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more controllers (e.g., microcontrollers) as one or more programs running on one or more processors (e.g., microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of ordinary skill in the art in light of this disclosure.

In addition, those skilled in the art will appreciate that the control mechanisms taught herein are capable of being distributed as a program product in a variety of tangible forms, and that an illustrative embodiment applies equally regardless of the particular type of tangible instruction bearing media used to actually carry out the distribution. Examples of tangible instruction bearing media include, but are not limited to, the following: recordable type media such as floppy disks, hard disk drives, CD ROMs, digital tape, flash drives, and computer memory.

The various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the present systems and methods in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims, but should be construed to include all machine-readable symbol scanning and processing systems and methods that read in accordance with the claims. Accordingly, the invention is not limited by the disclosure, but instead its scope is to be determined entirely by the following claims.

What is claimed is:

1. A method of error correction of a two-dimensional (2D) symbol, the method comprising:

reading, by a hardware processor, a plurality of codewords in the 2D symbol;

identifying, by the hardware processor, an optically ambiguous codeword of the plurality of codewords in the 2D symbol, wherein the optically ambiguous codeword corresponds to a codeword with minimum interior contrast level below a predefined minimum interior contrast level;

flagging, by the hardware processor, a specified number of codewords, as optically ambiguous, from the plurality of codewords based on the minimum interior contrast level associated with the plurality of codewords; and

correcting, by the hardware processor, errors in the specified number of optically ambiguous codewords based on, a location of the optically ambiguous codewords and an erroneous decoded value associated with the optically ambiguous codewords.

2. The method of claim **1**, wherein a dark/light threshold level of the optically ambiguous codeword corresponds to a contrast value that is utilized to determine a color of a cell in the optically ambiguous codeword.

3. The method of claim **2** further comprising:

identifying, by the hardware processor, a cell in the optically ambiguous codeword that has a contrast level closest to the dark/light threshold level.

4. The method of claim **3** further comprising:

determining, by the hardware processor, the minimum interior contrast level based on the contrast level associated with the identified cell.

5. The method of claim **1**, wherein the optically ambiguous codeword comprises a plurality of cells.

6. The method of claim **5** further comprising performing a contrast analysis on the 2D symbol, wherein the performing the contrast analysis further comprises:

determining, by the hardware processor, a reflectance of first color cells of the plurality of cells in each codeword of the plurality of codewords; and

determining, by the hardware processor, reflectance of second color cells of the plurality of cells in each codeword of the plurality of codewords.

7. The method of claim **6**, further comprising determining the optically ambiguous codeword as optically ambiguous when a level of contrast between the first color cells and the second color cells is insufficient for an unambiguous decoding of the codeword.

8. An electronic device for performing error correction of a two-dimensional (2D) symbol, the electronic device comprising:

an optical scanner configured to optically read, by an optical scanner of a symbol reader, a plurality of codewords in the 2D symbol;

a memory device configured to store an error correction equation;

a hardware processor configured to:

determine a location of a codeword of the plurality of codewords in the 2D symbol which is optically ambiguous, wherein determining the location comprises:

performing a contrast analysis on the 2D symbol, wherein performing of the contrast analysis comprises:

identifying a respective minimum interior contrast level for each codeword in the symbol;

flagging, as optically ambiguous, the codeword with minimum interior contrast level that satisfies a minimum interior contrast level criterion; and

execute the error correction equation based on the location of the optically ambiguous codeword in the 2D symbol to correct an error in the plurality of codewords.

9. The electronic device of claim **8**, wherein each codeword of the plurality of codewords comprises a plurality of cells, wherein the hardware processor is configured to perform the contrast analysis further by:

determining reflectance of first color cells of the plurality of cells in each codeword of the plurality of codewords; and

determining reflectance of second color cells of the plurality of cells in each codeword of the plurality of codewords.

10. The electronic device of claim **9**, wherein the hardware processor is configured to determine the location for the codeword by:

determining, for each codeword in the plurality of codewords, that a level of contrast between the first color cells and the second color cells is insufficient for an unambiguous decoding of the respective codeword.

11. The electronic device of claim **9**, wherein the hardware processor is configured to perform the contrast analysis by:

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determining a respective dark/light threshold level for each codeword of the plurality of codewords, wherein the dark/light threshold level is indicative of a reflectance above which a cell in a codeword is determined to be a first color, and below which a cell is determined to be a second color;

determining a level of difference between the reflectance of each cell of each codeword and the respective dark/light threshold level associated with each codeword of the plurality of codewords; and

determining the minimum interior contrast level for each codeword by determining whether a codeword of the plurality of codewords includes a cell with a lowest level of difference between the reflectance of the cell and the respective dark/light threshold level.

12. The electronic device of claim **11**, further comprising ranking each codeword of the 2D symbol based on the minimum interior contrast level.

13. The electronic device of claim **12**, wherein a specified number of codewords are flagged as optically ambiguous.

14. A computer readable, non-transitory storage medium storing instructions that, when executed by a hardware processor of a symbol reader, causes the hardware processor to execute a method of error correction for a two-dimensional (2D) symbol, the method comprises:

optically reading, by an optical scanner of a symbol reader, a plurality of codewords in the 2D symbol;

determining, via a hardware processor of the symbol reader, a location of a codeword which is optically ambiguous, the determining comprising:

performing a contrast analysis on the 2D symbol comprising:

identifying a respective minimum interior contrast level for each codeword in the symbol; and

flagging, as optically ambiguous, the codeword that has a minimum interior contrast level below a minimum interior contrast level threshold; and

executing, via the hardware processor, an error correction equation based on the location of the one or more optically ambiguous codewords in the 2D symbol to correct errors in the read plurality of codewords.

15. The computer readable, non-transitory storage medium of claim **14**, wherein each codeword of the plurality of codewords comprises a plurality of cells, wherein the performing the contrast analysis further comprises:

determining reflectance of first color cells of the plurality of cells in each codeword of the plurality of codewords; and

determining reflectance of second color cells of the plurality of cells in each codeword of the plurality of codewords.

16. The computer readable, non-transitory storage medium of claim **15**, wherein determining the location for the codeword which is optically ambiguous comprises:

determining, for each codeword in the plurality of codewords, that a level of contrast between the first color cells and the second color cells is insufficient for an unambiguous decoding of the respective codeword.

17. The computer readable, non-transitory storage medium of claim **15**, wherein performing the contrast analysis further comprises:

determining a respective dark/light threshold level for each codeword of the plurality of codewords, wherein the dark/light threshold level is indicative of a reflectance above which a cell in a codeword is determined to be a first color, and below which a cell is determined to be a second color;

determining a level of difference between the reflectance of each cell of each codeword and the respective dark/light threshold level associated with each codeword of the plurality of codewords; and

determining the minimum interior contrast level for each codeword by determining whether a codeword of the plurality of codewords includes a cell with a lowest level of difference between the reflectance of the cell and the respective dark/light threshold level.

18. The computer readable, non-transitory storage medium of claim **17**, further comprising ranking each codeword of the 2D symbol based on the minimum interior contrast level.

19. The computer readable, non-transitory storage medium of claim **14**, wherein a specified number of codewords are flagged as optically ambiguous.

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(54) ENHANCED MATRIX SYMBOL ERROR CORRECTION METHOD

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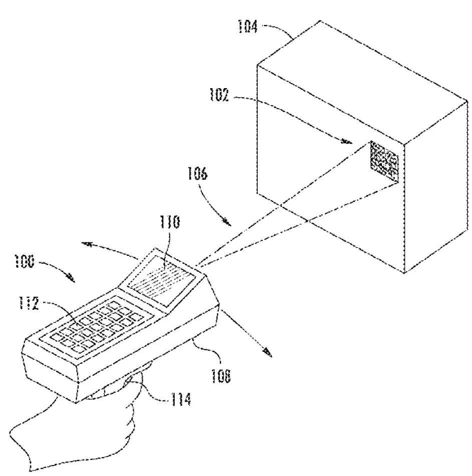
(57) **ABSTRACT**

A system and method for error correction for machine-readable symbols having data codewords, and having error correction (EC) codewords derived from the data codewords and redundantly indicating the location and data contents of the data codewords. The symbols use Reed-Solomon (RS) error correction to retrieve damaged codewords. RS error correction normally requires two EC codewords to identify both the location and data contents of a data codeword. The present system and method performs optical contrast analysis on the codewords, identifying those codewords with the lowest contrast levels (that is, the least difference between the reflectance of the black or white cells and the black/white threshold). Codewords with the lowest contrast levels are flagged as optically ambiguous, thereby marking, in the EC equations, the locations of the codewords most like to be in error. As a result, only a single EC codeword is required to retrieve the data for a flagged data codeword.

14 Claims, 8 Drawing Sheets



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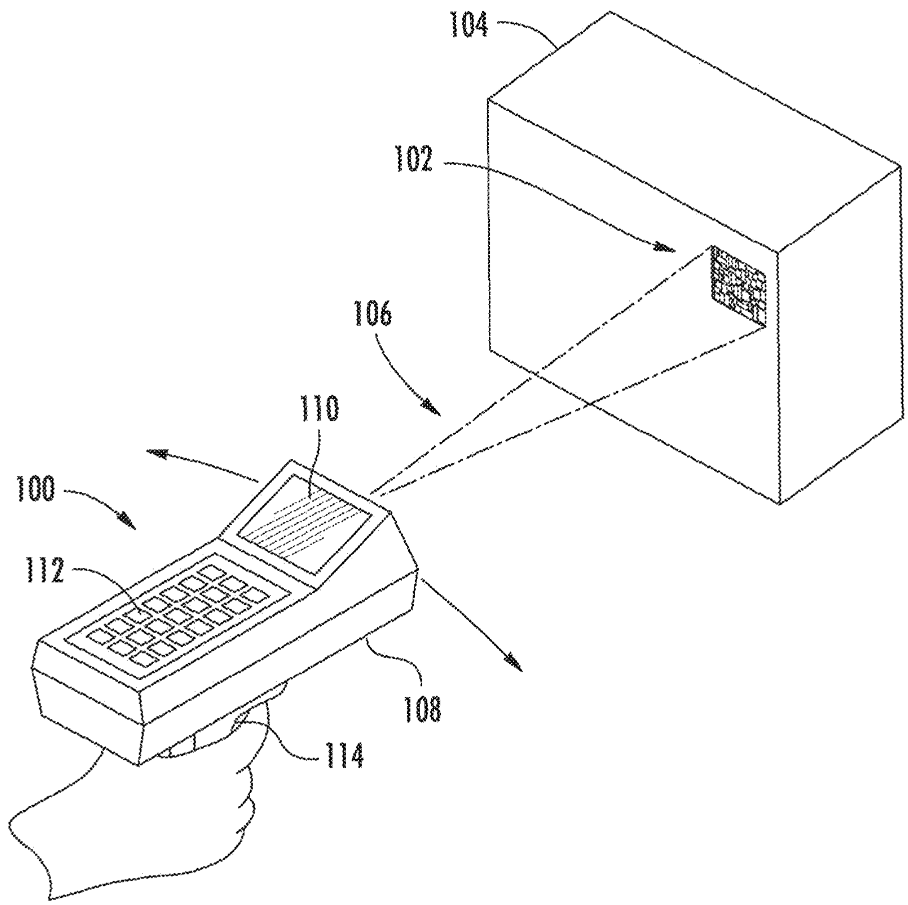

FIG. 1

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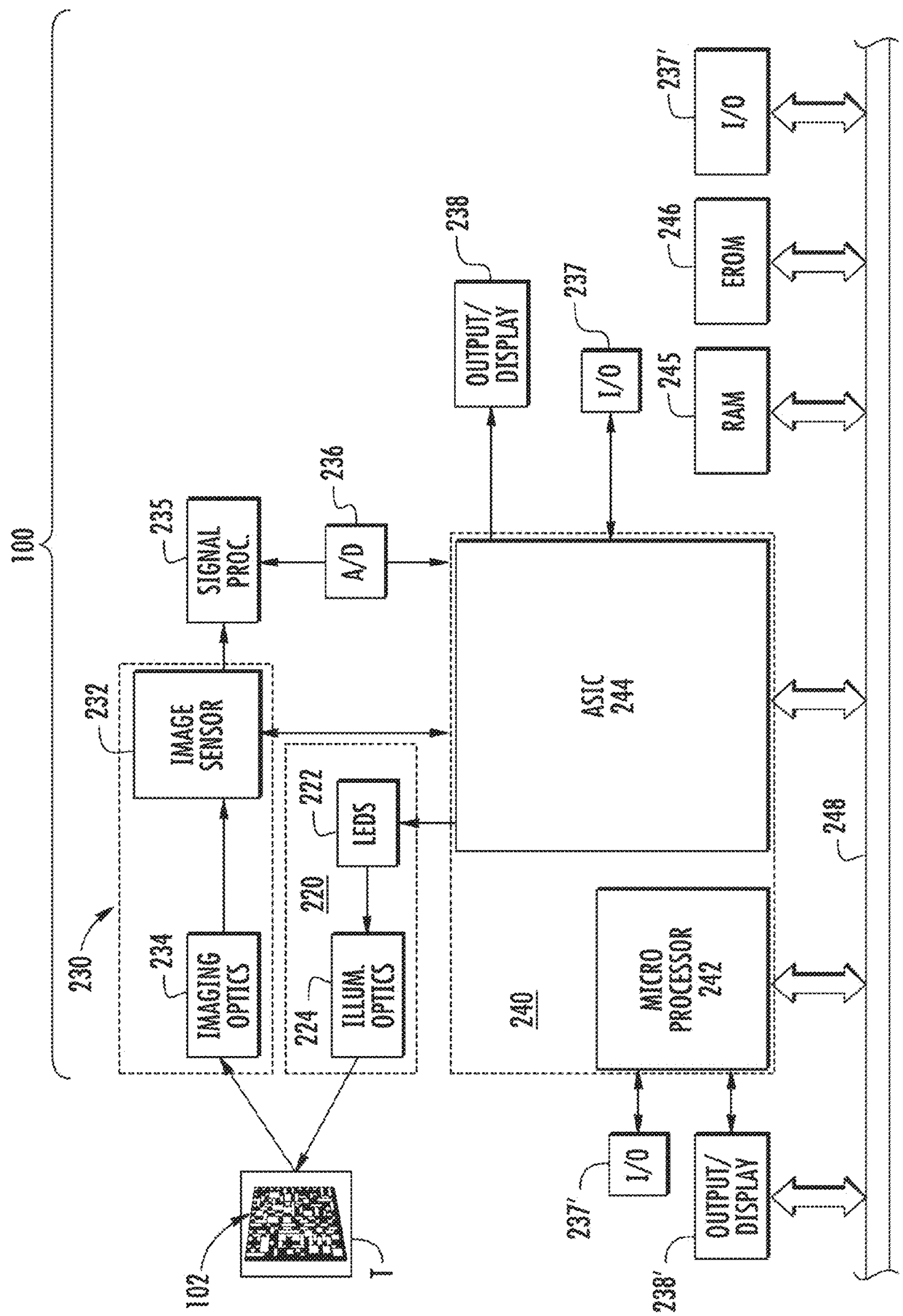
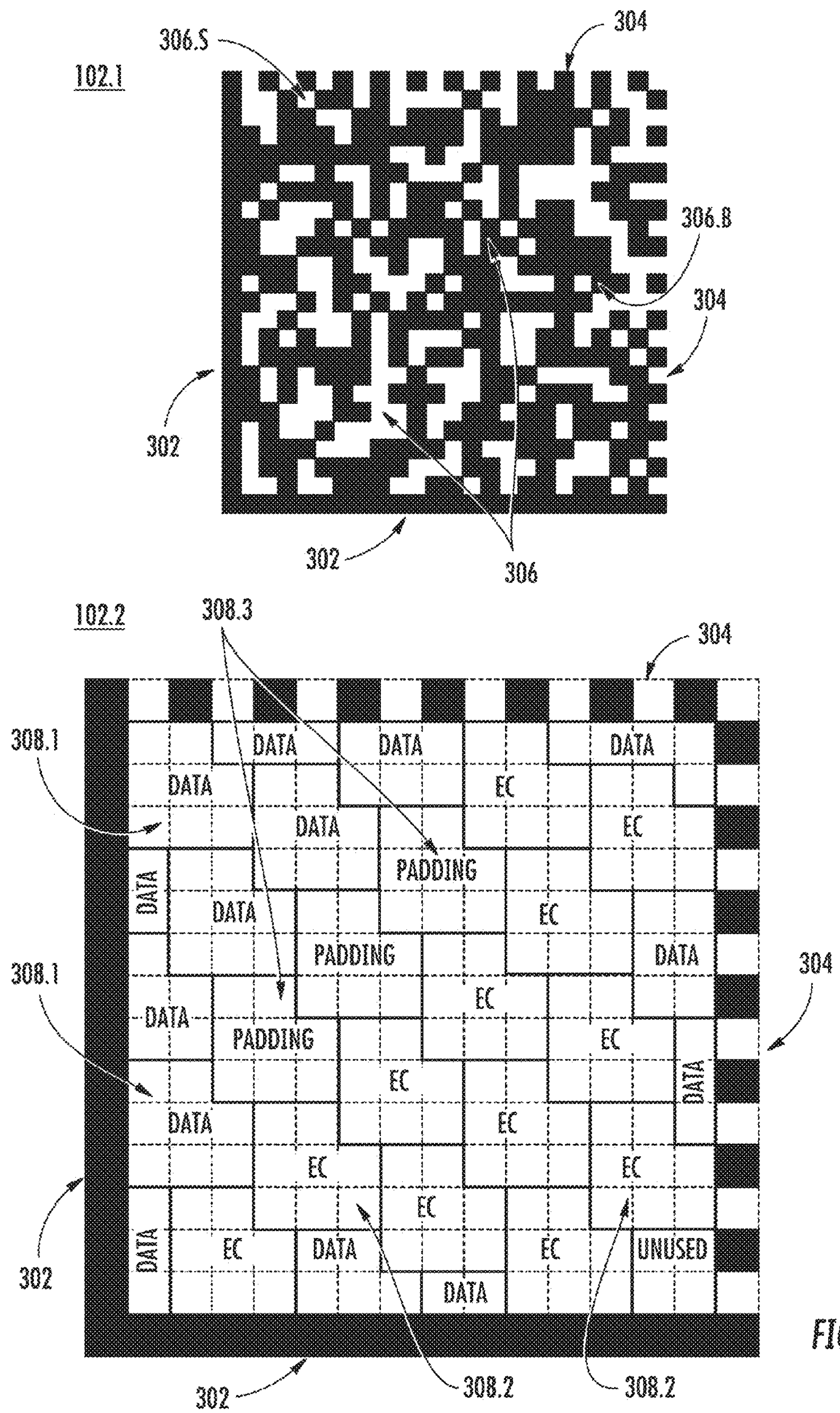
FIG. 2


100
230
232
IMAGE SENSOR
234
IMAGING OPTICS
235
SIGNAL PROC.
236
A/D
220
222
LEDS
224
ILLUM. OPTICS
238
OUTPUT/ DISPLAY
237
I/O
240
ASIC 244
MICRO PROCESSOR 242
245
RAM
246
EROM
237'
I/O
248
102
T
238'
OUTPUT/ DISPLAY

PX-218



102.1
306.5
304
306.8
304
302
302
306
102.2
308.3
304
308.1
DATA
DATA
DATA
DATA
EC
DATA
EC
PADDING
DATA
DATA
EC
PADDING
DATA
308.1
304
DATA
EC
PADDING
EC
EC
DATA
DATA
EC
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EC
DATA
EC
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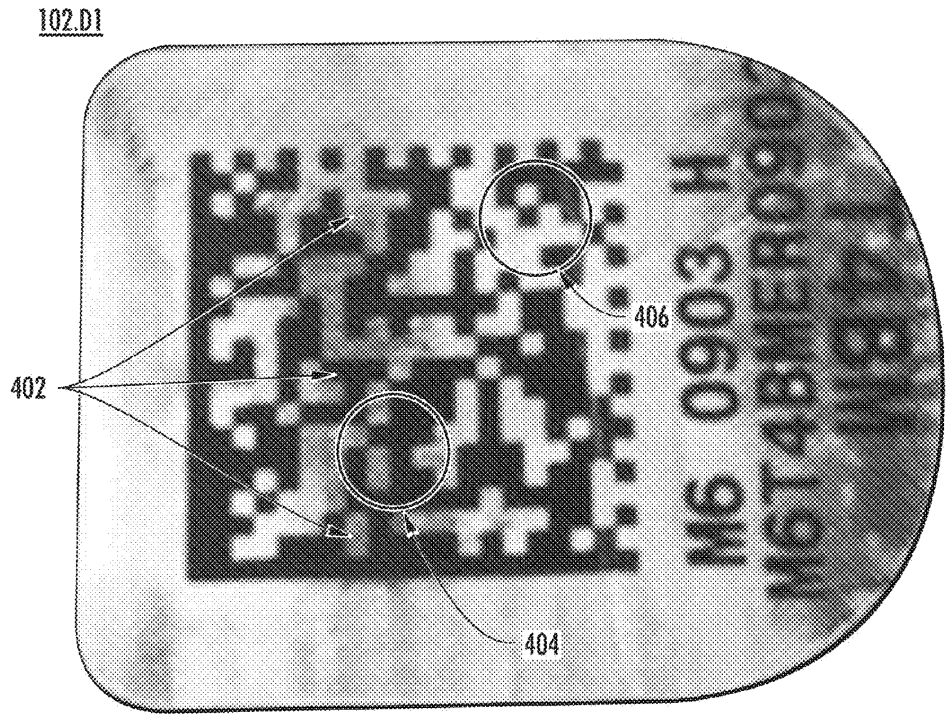
308.2

FIG. 3

PX-218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402
406
404
M6 0903 H
M6T 4B1ER060

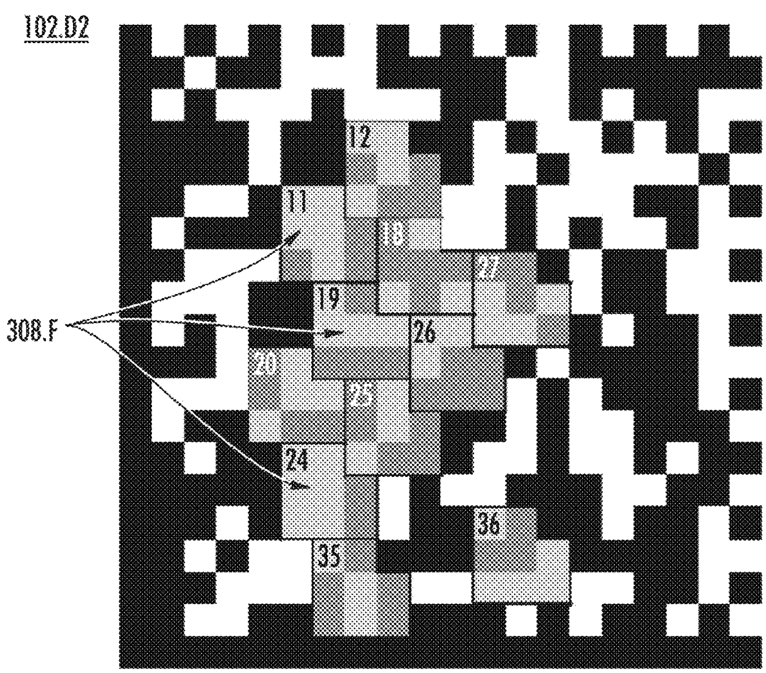
102.D2
308.F
12
11
18
27
19
26
20
25
24
36
35

FIG. 4

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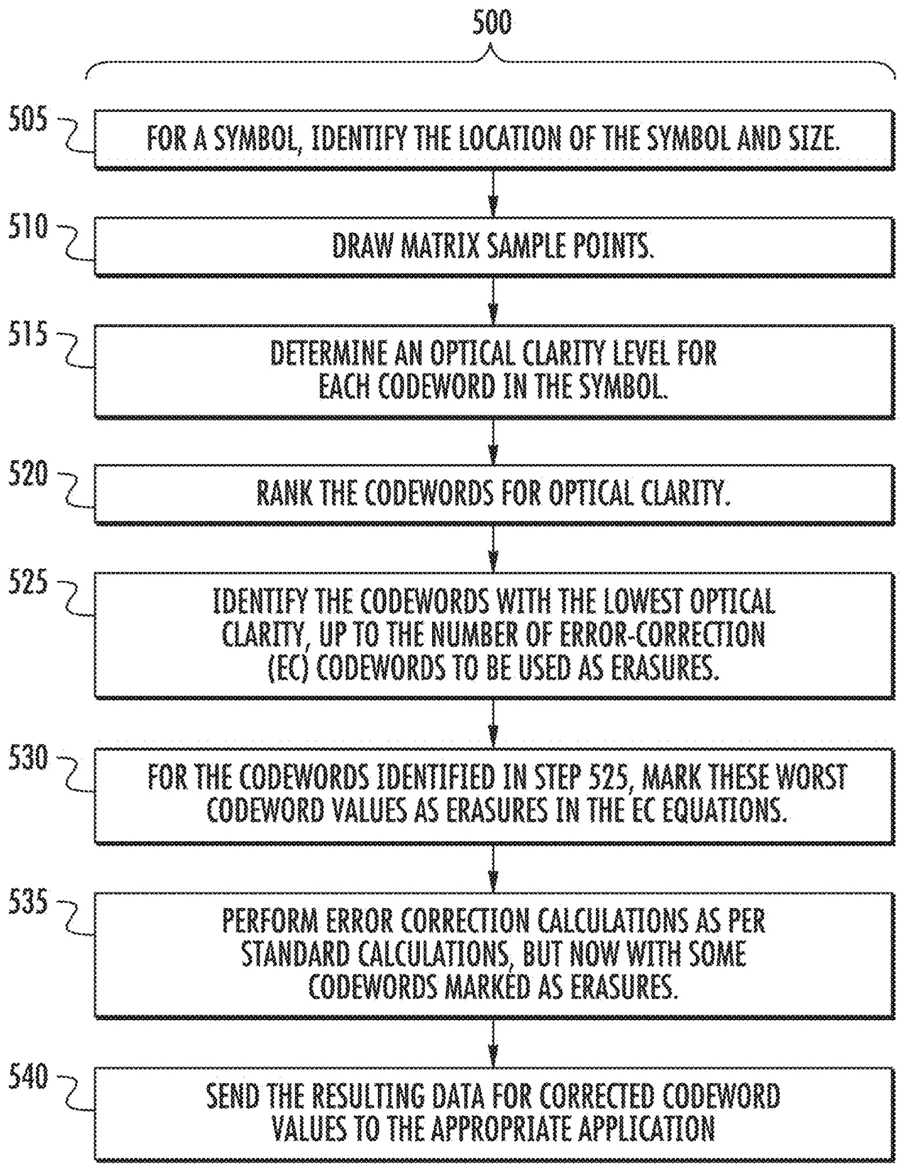
500
505
FOR A SYMBOL, IDENTIFY THE LOCATION OF THE SYMBOL AND SIZE.
510
DRAW MATRIX SAMPLE POINTS.
515
DETERMINE AN OPTICAL CLARITY LEVEL FOR EACH CODEWORD IN THE SYMBOL.
520
RANK THE CODEWORDS FOR OPTICAL CLARITY.
525
IDENTIFY THE CODEWORDS WITH THE LOWEST OPTICAL CLARITY, UP TO THE NUMBER OF ERROR-CORRECTION (EC) CODEWORDS TO BE USED AS ERASURES.
530
FOR THE CODEWORDS IDENTIFIED IN STEP 525, MARK THESE WORST CODEWORD VALUES AS ERASURES IN THE EC EQUATIONS.
535
PERFORM ERROR CORRECTION CALCULATIONS AS PER STANDARD CALCULATIONS, BUT NOW WITH SOME CODEWORDS MARKED AS ERASURES.
540
SEND THE RESULTING DATA FOR CORRECTED CODEWORD VALUES TO THE APPROPRIATE APPLICATION

FIG. 5

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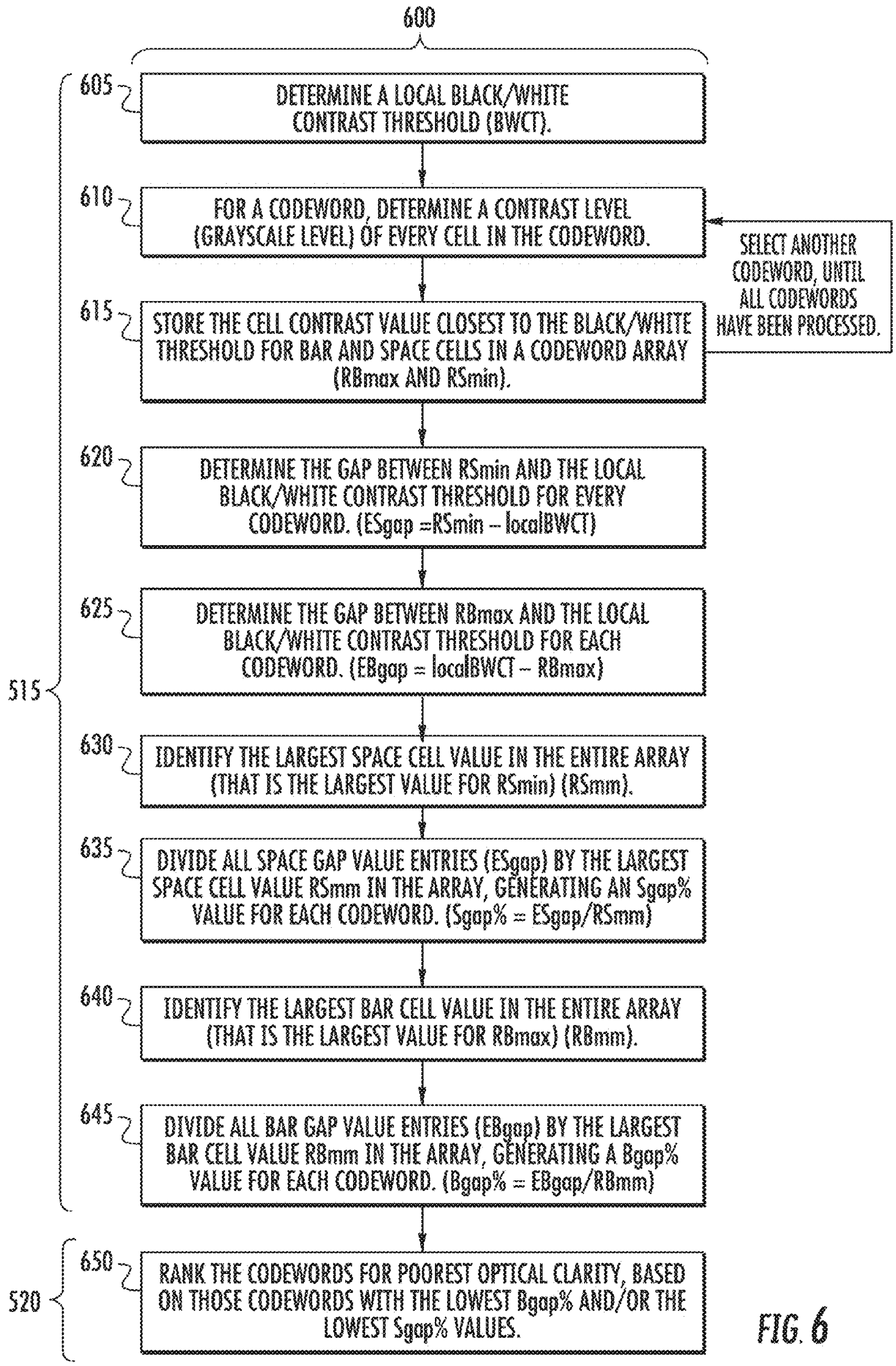
600
605
DETERMINE A LOCAL BLACK/WHITE CONTRAST THRESHOLD (BWCT).
610
FOR A CODEWORD, DETERMINE A CONTRAST LEVEL (GRAYSCALE LEVEL) OF EVERY CELL IN THE CODEWORD.
SELECT ANOTHER CODEWORD, UNTIL ALL CODEWORDS HAVE BEEN PROCESSED.
615
STORE THE CELL CONTRAST VALUE CLOSEST TO THE BLACK/WHITE THRESHOLD FOR BAR AND SPACE CELLS IN A CODEWORD ARRAY (RBmax AND RSmin).
620
DETERMINE THE GAP BETWEEN RSmin AND THE LOCAL BLACK/WHITE CONTRAST THRESHOLD FOR EVERY CODEWORD. (ESgap =RSmin – localBWCT)
625
DETERMINE THE GAP BETWEEN RBmax AND THE LOCAL BLACK/WHITE CONTRAST THRESHOLD FOR EACH CODEWORD. (EBgap = localBWCT – RBmax)
515
630
IDENTIFY THE LARGEST SPACE CELL VALUE IN THE ENTIRE ARRAY (THAT IS THE LARGEST VALUE FOR RSmin) (RSmm).
635
DIVIDE ALL SPACE GAP VALUE ENTRIES (ESgap) BY THE LARGEST SPACE CELL VALUE RSmm IN THE ARRAY, GENERATING AN Sgap% VALUE FOR EACH CODEWORD. (Sgap% = ESgap/RSmm)
640
IDENTIFY THE LARGEST BAR CELL VALUE IN THE ENTIRE ARRAY (THAT IS THE LARGEST VALUE FOR RBmax) (RBmm).
645
DIVIDE ALL BAR GAP VALUE ENTRIES (EBgap) BY THE LARGEST BAR CELL VALUE RBmm IN THE ARRAY, GENERATING A Bgap% VALUE FOR EACH CODEWORD. (Bgap% = EBgap/RBmm)
650
520
RANK THE CODEWORDS FOR POOREST OPTICAL CLARITY, BASED ON THOSE CODEWORDS WITH THE LOWEST Bgap% AND/OR THE LOWEST Sgap% VALUES.

FIG. 6

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700

CW	RSmin	RBmax	ESgap	Sgap% (702)	EBgap	Bgap% (702)	RANK
1	D0	58	5B	85	1D	47	
2	B8	47	43	63	2E	74	
3	B8	40	43	63	35	85	
4	AF	47	3A	54	2E	74	
5	A0	3F	2B	40	36	87	
6	DF	47	6A	99	2E	74	
7	D0	40	5B	85	35	85	
8	D8	3F	63	93	36	87	
9	DF	3F	6A	99	36	87	
10	A8	3F	33	48	36	87	
11!	7F	3F	0A	09	36	87	4
12!	88	3F	13	18	36	87	7
13	AF	40	3A	54	35	85	
14	C0	3F	4B	70	36	87	
15	BF	3F	4A	69	36	87	
16	DF	3F	6A	99	36	87	
17	C0	3F	4B	70	36	87	
18!	77	38	02	02	3D	98	2
19!	77	3F	02	02	36	87	1
20!	9F	40	2A	39	35	85	12
21	D7	3F	62	92	36	87	
22	E0	67	6B	100	0E	23	9
23	C8	40	53	78	35	85	
24!	80	3F	0B	10	36	87	6
25!	88	3F	13	18	36	87	8
26!	90	38	1B	25	3D	98	11
27!	A7	3F	32	47	36	87	XXX
28	DF	40	6A	99	35	85	
29	DF	40	6A	99	35	85	
30	D0	3F	5B	85	36	87	
31	CF	38	5A	84	3D	98	
32	BF	40	4A	69	35	85	
33	AF	38	3A	54	3D	98	
34	7F	3F	0A	09	36	87	5
35!	78	3F	03	03	36	87	3
36!	8F	3F	1A	24	36	87	10
37	CF	3F	5A	84	36	87	
38	D7	37	62	92	3E	100	
39	D0	38	5B	85	3D	98	
40	C8	3F	53	78	36	87	

FIG. 7

HONEYWELL-00240655

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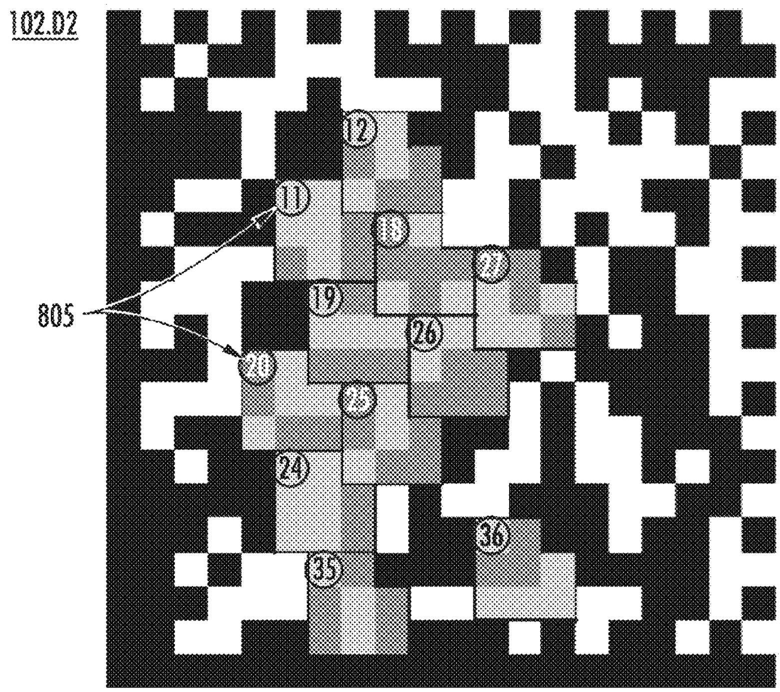
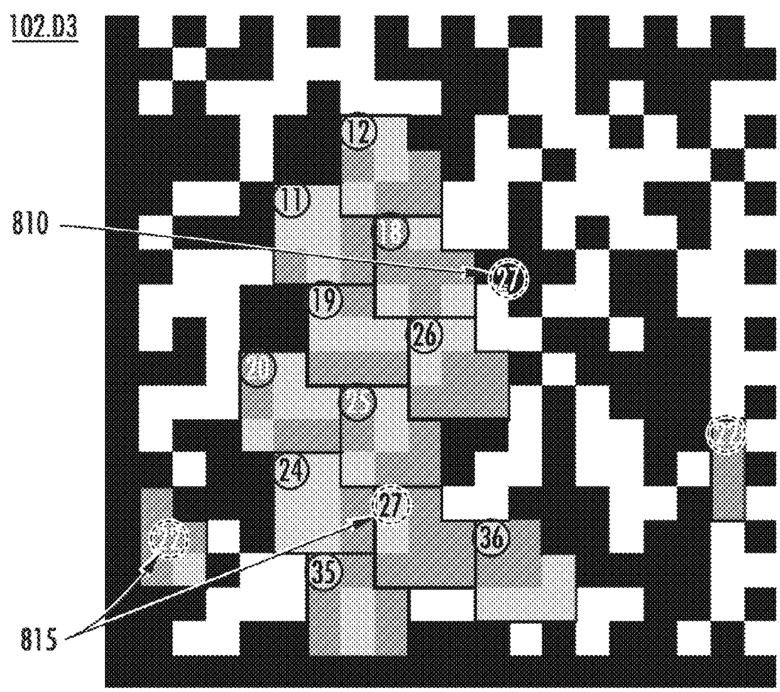


ACTUAL CODEWORDS IN ERROR AS INTERPRETED BY A SCANNER IN THE FIELD.



SAME SYMBOL, CODEWORDS-IN-ERROR AS ANALYZED BY ALGORITHM.

FIG. 8

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ENHANCED MATRIX SYMBOL ERROR CORRECTION METHOD

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for decoding machine-readable symbols, and more particularly, to a method and apparatus for decoding symbols requiring error correction.

BACKGROUND

Machine-readable symbols provide a means for encoding information in a compact printed form (or embossed form) which can be scanned and then interpreted by an optical-based symbol detector. Such machine readable symbols are often attached to (or impressed upon) product packaging, food products, general consumer items, machine parts, equipment, and other manufactured items for purposes of machine-based identification and tracking.

One exemplary type of machine-readable symbol is a bar code that employs a series of bars and white spaces vertically oriented along a single row. Groups of bars and spaces correspond to a codeword. The codeword is associated with an alpha-numeric symbol, one or more numeric digits, or other symbol functionality.

To facilitate encoding of greater amounts of information into a single machine-readable symbol, two-dimensional bar codes have been devised. These are also commonly referred to as stacked, matrix and/or area bar codes. Examples of such two-dimensional symbologies include Data Matrix, Code One, PDF-417, MaxiCode, QR Code, and Aztec Code. 2D matrix symbologies employ arrangements of regular polygon-shaped cells (also called elements or modules) where the center to center distance of adjacent elements is uniform. Typically, the polygon-shaped cells are squares. The specific arrangement of the cells in 2D matrix symbologies represents data characters and/or symbology functions.

As an example of a 2D matrix symbol technology, a Data Matrix code is a two-dimensional matrix barcode consisting of high-contrast "cells" (typically black and white cells) or modules arranged in either a square or rectangular pattern. The information to be encoded can be text or numeric data, or control symbols. The usual data size ranges from a few bytes up to 1556 bytes. Specific, designated, standardized groups of cells—typically eight cells—are each referred to as a "symbol character." The symbol characters have values which are referred to as "codewords." With a black cell interpreted as a 0 (zero) and a white cell interpreted as a 1 (one), an eight-cell codeword can code for numbers 0 through 255; in turn, these numeric values can be associated with alphanumeric symbols through standard codes such as ASCII, EBCDIC, or variations thereon, or other functionality.

The codewords—that is, the designated groups of cells in a symbol—have specific, standardized positions within the overall symbol. The interpretation of a symbol in a given context (for example, for a given manufacturer and/or a given product) therefore depends on the codewords within the symbol; and in particular, the interpretation depends on both: (i) the contents of each codeword (that is, the pattern of cells in each codeword), and (ii) the placement or position of each codeword in the symbol.

Typically, for sequential alphanumeric data (for example, a product identification number or a street address), each sequential data character is assigned to the symbols of a codeword in a standardized order. For example, the order may be left-to-right along the rows of the symbol, or according to a standardized diagonal pattern of placement. Because the codewords have specific, standards-specified placements within a symbol—and because no information about the placement is contained in the symbol character—the symbols may also be referred to as "matrix symbols" or "matrix symbology barcodes."

Bar code readers are employed to read the matrix symbols using a variety of optical scanning electronics and methods. Ideally, the machine-readable symbols which are scanned by a bar code reader are in perfect condition, with all of the cells of consistent, uniform size; each cell being fully filled with either total black or total white; and the contrast between black and white cells being 100%.

In real, practical application the machine-readable symbols which are scanned by a bar code reader may be imperfect. They may be smudged by external substances (grease, dirt, or other chemicals in the environment); or the surface on which the symbols were printed may be stretched, compressed, or torn; or the printing process itself may be flawed (for example, due to low ink levels in a printer, clogged printheads, etc.). The defects in actual symbols may introduce errors in the machine reading process.

To address these practical problems, error correction techniques are often used to increase reliability: even if one or more cells are damaged so as to make a codeword unreadable, the unreadable codeword can be recovered through the error-correction process, and the overall message of the symbol can still be read.

For example, machine-readable symbols based on the Data Matrix ECC 200 standard employ Reed-Solomon codes for error and erasure recovery. ECC 200 allows the routine reconstruction of the entire encoded data string when the symbol has sustained 25% damage (assuming the matrix can still be accurately located).

Under this standard, approximately half the codewords in a symbol are used directly for the data to be represented, and approximately half the codewords are used for error correction. The error-correction (EC) symbols are calculated using a mathematical tool know as the Reed-Solomon algorithm. The codewords for the symbol are the input to the Reed-Solomon algorithm, and the error-correction (EC) symbols are the output of the Reed-Solomon algorithm. The complete machine-readable symbol includes both the data codewords and the EC codewords.

For a given symbol format (such as Data Matrix, PDF-417, QR-Code, Aztec Code, and others), and for a given size of the symbol matrix, there are a fixed, designated numbers of EC codewords. To recover any one, particular damaged (unreadable) codeword, two things must be recovered: (i) the location of the damaged data codeword within the symbol, and (ii) the contents (the bit pattern) of the damaged data codeword. In turn, to recover both the location and the bit pattern for a single codeword requires two of the available EC symbols. It follows that if a machine-readable symbol has two damaged codewords, four EC codewords are required to recover the full symbol. Generally, if a symbol has "N" damaged codewords, then 2*N EC codewords are required to recover the full symbol.

The number of EC codewords in a symbol is limited. This places a limit on the number of damaged, unreadable data codewords which can be recovered. Generally with error correction techniques, and using present methods, the number of damaged data codewords which can be recovered is half the total number of EC codewords. For example, in a Data Matrix symbol with 16×16 cells, the total number of EC codewords is 12. This means that at most 6 damaged data

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codewords can be recovered. If more than 6 of the data codewords are damaged, the complete symbol may be unreadable.

However, if the location of the data codeword in error is already known, then only one EC codeword is needed to correct the error. This technique is called "erasure decoding". Unfortunately, in Matrix Code symbols generally, the location of the errors is not known.

Therefore, there exists a need for a system and method for recovering more damaged data codewords in a symbol than may be recovered based on only the error-correcting symbols by themselves. More particularly, what is needed is a system and method for determining the location of a damaged or erroneous data codeword, independent of the information stored in the EC codewords.

SUMMARY

Accordingly, in one aspect, the present invention solves the problem of not being able to use erasure decoding with matrix symbologies by evaluating the gray-level information available in the scanner and keeping track of those codewords with the least contrast difference. The decoder then utilizes erasure decoding on these least-contrast codewords. Since the location of the erroneous data codewords has been estimated via the contrast detection, only one EC codeword is required to recover the data in the damaged codeword. (And so, only one EC codeword is required to fully recover the damaged data codeword, both its location and data.)

Because only one EC codeword is required instead of two, more EC codewords remain unused and available for decoding other possible errors. This increases the total number of data codewords that can be corrected. This is particularly useful in applications where symbols get dirty (e.g. automotive assembly), damaged (e.g. supply chain), have specular components (e.g. direct part marking (DPM)) and need to be scanned over a greater range (e.g. all applications).

The algorithm of the present invention has the effect of nearly doubling the number of codewords that can be corrected in matrix symbology decodes, thereby greatly improving the performance over what is currently available.

The foregoing illustrative summary, as well as other exemplary objectives and/or advantages of the invention, and the manner in which the same are accomplished, are further explained within the following detailed description and its accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an exemplary hand-held symbol reader acquiring data from a machine-readable symbol.

FIG. **2** is an internal block diagram of an exemplary symbol reader for acquiring data from a machine-readable symbol

FIG. **3** illustrates several exemplary machine-readable 2D symbols.

FIG. **4** provides two views of an exemplary 2D symbol which is damaged.

FIG. **5** is a flow-chart of an exemplary method for optically enhanced Reed-Solomon error-correction for a 2D symbol.

FIG. **6** is a flow-chart of an exemplary method for contrast analysis for a 2D symbol as part of enhanced Reed-Solomon error correction.

FIG. **7** presents an exemplary array of codeword contrast values used for enhanced error correction by applying contrast analysis to a flawed codeword.

FIG. **8** illustrates an exemplary case-study of enhanced error correction by applying contrast analysis to a flawed codeword.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various embodiments. However, one skilled in the art will understand that the invention may be practiced without these details. In other instances, well-known structures associated with imagers, scanners, and/or other devices operable to read machine-readable symbols have not been shown or described in detail to avoid unnecessarily obscuring descriptions of the embodiments.

Unless the context requires otherwise, throughout the specification and claims which follow, the word "comprise" and variations thereof, such as, "comprises" and "comprising" are to be construed in an open sense, that is as "including, but not limited to."

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

The headings provided herein are for convenience only and do not interpret the scope or meaning of the claimed invention.

Symbol Reader

The present system and method embraces devices designed to read machine-readable symbols.

In an exemplary embodiment, such a device may be a hand-held scanner. FIG. **1** is a perspective view of an exemplary hand-held symbol reader **100** acquiring data from a machine-readable symbol **102**.

The machine-readable symbol **102** is affixed to a package **104** or the like such that the user points the hand-held symbol reader **100** towards the machine-readable symbol **102**. The symbol reader **100** may be a line scanner operable to emit and sweep a narrow beam of electromagnetic energy across a field-of-view **106** over two-dimensional (2D) machine-readable symbol **102**. In other embodiments, an aperture means, mirror, lens or the like is adjusted to sweep across a symbol line to receive returning electromagnetic energy from a relatively small portion (e.g., cell) of the machine-readable symbol, which is detected by an optical detector system.

In yet other embodiments, a 2D array symbol reader acquires a captured image of the machine-readable symbol (and a suitable region of quiet area around the machine-readable symbol). For the present system and method, which relies upon a contrast analysis of the cells within the symbol **102**, the acquisition of a captured image of the symbol may be a preferred method of operation for the symbol reader **100**. Suitable image processing hardware **235** and software running on processors **242**, **244** are used to deconstruct the capture image to determine the data bits represented by the cells, and to perform the contrast analysis of the present system and method (see FIG. **2** below).

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The machine-readable symbol reader **100** is illustrated as having a housing **108**, a display **110**, a keypad **112**, and an actuator device **114**. Actuator device **114** may be a trigger, button, or other suitable actuator operable by the user to initiate the symbol reading process.

The machine-readable symbol **102** shown in the figure is intended to be generic and, thus, is illustrative of the various types and formats of machine-readable symbols. For example, some machine-readable symbols may consist of a single row of codewords (e.g., barcode). Other types of machine-readable symbols (e.g., matrix or area code) may be configured in other shapes, such as circles, hexagons, rectangles, squares and the like. It is intended that many various types and formats of machine-readable symbologies be included within the scope of the present system and method.

Symbol Reader Internal Block Diagram

An internal block diagram of an exemplary symbol reader **100** of a type which may implement the present system and method is shown in FIG. **2**.

In one embodiment of the present system and method, the symbol reader **100** may be an optical reader. Optical reader **100** may include an illumination assembly **220** for illuminating a target object T, such as a 1D or 2D bar code symbol **102**, and an imaging assembly **230** for receiving an image of object T and generating an electrical output signal indicative of the data which is optically encoded therein. Illumination assembly **220** may, for example, include an illumination source assembly **222**, such as one or more LEDs, together with an illuminating optics assembly **224**, such as one or more reflectors, for directing light from light source **222** in the direction of target object T. Illumination assembly **220** may be eliminated if ambient light levels are certain to be high enough to allow high quality images of object T to be taken.

In an embodiment, imaging assembly **230** may include an image sensor **232**, such as a 2D CCD or CMOS solid state image sensor, together with an imaging optics assembly **234** for receiving and focusing an image of object T onto image sensor **32**. The array-based imaging assembly shown in FIG. **2** may be replaced by a laser scanning based imaging assembly comprising a laser source, a scanning mechanism, emit and receive optics, a photodetector and accompanying signal processing circuitry. The field of view of the imaging assembly **230** will depend on the application. In general, the field of view should be large enough so that the imaging assembly can capture a bit map representation of a scene including an image data reading region at close reading range.

In an embodiment of the present system and method, exemplary symbol reader **100** of FIG. **2** also includes programmable controller **240** which may comprise an integrated circuit microprocessor **242** and an application specific integrated circuit (ASIC) **244**. Processor **242** and ASIC **244** are both programmable control devices which are able to receive, output and process data in accordance with a stored program stored in either or both of a read/write random access memory (RAM) **245** and an erasable read only memory (EROM) **246**. Processor **242** and ASIC **244** are also both connected to a common bus **248** through which program data and working data, including address data, may be received and transmitted in either direction to any circuitry that is also connected thereto. Processor **242** and ASIC **244** may differ from one another, however, in how they are made and how they are used.

In one embodiment, processor **242** may be a general purpose, off-the-shelf VLSI integrated circuit microprocessor which has overall control of the circuitry of FIG. **2**, but which devotes most of its time to decoding image data stored in RAM **245** in accordance with program data stored in EROM **246**. Processor **244**, on the other hand, may be a special purpose VLSI integrated circuit, such as a programmable logic or gate array, which is programmed to devote its time to functions other than decoding image data, and thereby relieve processor **242** from the burden of performing these functions.

In an alternative embodiment, special purpose processor **244** may be eliminated entirely if general purpose processor **242** is fast enough and powerful enough to perform all of the functions contemplated by the present system and method. It will, therefore, be understood that neither the number of processors used, nor the division of labor there between, is of any fundamental significance for purposes of the present system and method.

In an embodiment, exemplary symbol reader **100** includes a signal processor **235** and an analog-to-digital (A/D) chip **236**. These chips together take the raw data from image sensor **232** and convert the data to digital format, which in an exemplary embodiment may be a gray-level digital format, for further processing by programmable controller **240**.

In an embodiment, the system and method of the present invention employs algorithms stored in EROM **246** which enable the programmable controller **240** to analyze the image data from signal processor **235** and A/D **236**. In an embodiment, and as described further below, this image analysis may include analyzing gray-level information (contrast levels) in the image data. In an embodiment, and in part based on the contrast level analysis, programmable controller **240** may then implement an improved system and method of error correction for matrix symbols by relying on optical contrast-level analysis, as also described further below.

Exemplary symbol reader **100** may also include input/output (I/O) circuitry **237**, for example to support the use of the keyboard **112** and trigger **114**. Symbol reader **100** may also include output/display circuitry **238** to support display **110**.

Exemplary Symbols

FIG. **3** illustrates several exemplary machine-readable 2D symbols **102** labeled **102.1** and **102.2**.

Symbol **102.1** is an exemplary machine-readable symbol encoded according to the Data Matrix barcode (ECC 200) standard. The symbol **102.1**, which is a 24×24 array, has two solid black borders **302** forming an "L-shape" which are the finder pattern, enabling the symbol reader to determine the location and orientation of the 2D symbol. The symbol also has two opposing borders of alternating dark and light cells which form a "timing pattern" **304** which help the symbol reader identify the size (the number of rows and columns) of the symbol.

Interior to the finder pattern **302** and timing pattern **304** are rows and columns of interior cells **306** which encode information. As may be evident from the figure, an ideal machine-readable symbol has a very high contrast level between the first color dark cells and the second color light cells, in many cases achieved by employing clearly printed, unobscured cells which are either all black or all white.

Symbol **102.2** is an exemplary 16×16 machine-readable symbol encoded according to the Data Matrix barcode (ECC 200) standard. In symbol **102.2**, and for purposes of illustration only, the interior black data cells are omitted, and

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boundaries between the interior cells **306** are suggested by shaded, dotted lines which are not normally present in actual printed data matrix symbols.

Also not normally present in actual printed symbols, but included here for purposes of illustration, are solid borders which indicate the boundaries of the codewords **308** formed by the interior cells **306**. In an embodiment, each codeword **308** is composed of eight cells representing a single byte of data. It will be seen that there are several types of codewords, including data codewords **308.1** which encode the actual data to be represented by the symbol; error-correcting (EC) codewords **308.2** which are generated from the data codewords according to the Reed-Solomon algorithm; and padding codewords **308.3**.

The figure also identifies one exemplary bar (black) cell **306**.B and one exemplary space (white) cell **306**.S.

The illustration here of machine-readable symbols based on the Data Matrix barcode standard, as well as the size, shape, and data contents illustrated, are exemplary only and should not be construed as limiting. The present system and method is applicable to a wide variety of 2D matrix barcodes according to a variety of known standards, as well as being applicable to other 2D machine-readable symbols which may be envisioned in the future.

Symbol Errors

As discussed above, the data content of symbols **102** is stored or presented in the form of cells **306** of contrasting colors within codewords **308**. In an embodiment of the present system and method, the light cells (typically white) represent ones (1's) and the dark cells (typically black) represent zeros (0's). In an alternative embodiment, a light cell represents zero (0) and the dark cells represent (1). In alternative embodiments, other colors or levels of shading may be employed. As a general matter, however, for the coding to be effective the symbol reader **100** must be readily able to distinguish the dark cells from the light cells. Also, the data is stored not only in terms of the cells **306** per se, but also in terms of the positions of the cells **306** within the codewords **308**, and the positions of each codeword **308** within the symbol **102**.

If a symbol **102** is damaged, there may be insufficient contrast between light cells and dark cells for the symbol reader **100** to reliable distinguish the cells. Similarly, damage to the symbol may render it difficult for the symbol reader to identify the location or boundaries of cells **306** and codewords **308**. In other cases damage to cells **306** can cause a change from black to white or vice-versa. This in turn calls upon the error-correction methods, such as Reed-Solomon, already discussed above. The present system and method is intended to augment Reed-Solomon and similar error-correction methods with information based on contrast analysis.

FIG. **4** provides two views **102**.D**1**, **102**.D**2** of an exemplary symbol which is damaged, so that the original high-contrast has been lost while the symbol **102** is in use in the field.

In the first view, the damaged symbol **102**.D**1** shown in the figure was photographed in a real-world automotive manufacturing plant. It is apparent that there is a dark vertical scuff mark **402** which is approximately down the middle of the symbol **102**.D**1**. The scuffing is sufficiently dark that, when read with a standard symbol reader **100**, the reader **100** mistakes many individual cells **306** for black when (as printed, and without damage or scuffing) they are white cells. This in turns causes codeword errors. This symbol **102**.D**1** will not read with current scanners.

The actual value of the codewords in symbol **102**.D**1** is listed here (codewords before the colon are data codewords, those after the colon are error-correction codewords):

237 151 230 204 27 207 144 165 112 27 13 43 222 60 125 34 137 186 71 163 223 254:96 9 171 31 209 21 131 100 111 146 225 95 109 112 182 218 118 203

The values for the codewords determined by a symbol reader **100** are shown here, with the incorrect codewords underlined:

237 151 230 204 27 207 144 165 112 27 <u>173</u> <u>111</u> 222 60 125 34 137 <u>191</u> <u>127</u> <u>235</u> 223 254:96 <u>25</u> <u>175</u> <u>191</u> <u>208</u> 21 131 100 111 146 225 95 <u>111</u> <u>116</u> 182 218 118 203

As is apparent in the image of symbol **102**.D**1**, throughout the smudged region **402** the contrast between many individual cells is small, and is close to the threshold level between black and white. Compare for example a cluster of low contrast cells **404** within the smudged region **402** with a non-damaged, machine-readable high contrast region **406**.

In the second view, the damaged symbol **102**.D**2** is illustrated as it was interpreted by an actual scanner **100** in the field. As shown by the codewords with shaded cells **306** in the illustration, there were eleven codewords **308** which provided flawed readings from the scanner **100**, and may be described as flawed codewords **308**.F.

Erasure Vs. Error:

By way of terminology, it is noted here that if the position of an erroneous codeword is known, but the data is not known (or is ambiguous), the codeword is referred to as an "erasure." If the data of an erroneous codeword is unknown and the position of the codeword is also unknown, the codeword is referred to as an "error."

Reed-Solomon Error Correction

In an embodiment, the present system and method includes application of error-correcting codes and analyses, augmented with optical analysis of a machine-readable symbol **102**, to detect and correct errors in the machine-readable symbol **102**. Various mathematical methods of error correction are well-known in the art, and a detailed description is beyond the scope of this document. However, review of a few basic elements of an exemplary error-correction method may aid in the understanding of the present system and method.

All standardized 2D matrix symbologies utilize the Reed-Solomon methodology. In Reed-Solomon codes, a set of data elements, such as bytes of data, may be redundantly encoded in a second set of error-correcting elements (also typically in byte form), which for present purposes can be referred to as EC codewords **308.2**. The error-correcting codewords are transmitted or presented along with the principle data elements, enabling reconstruction of damaged data elements.

Methods of constructing the Reed-Solomon EC codewords (based on a given, particular data set) are outside the scope of this document. It suffices for present purposes to understand that Reed-Solomon-derived EC codewords **308.2** can be calculated, and the resulting EC codewords are included as part of 2D matrix symbols, as already described above.

There are a variety of methods of decoding a message with Reed-Solomon error correction. In one exemplary method, the values of the data codewords **308.1** of a symbol **102** are viewed as the coefficients of a polynomial s(x) that is subject to certain constraints (not discussed here):

$$S(x) = \sum_{i=0}^{n-1} c_i x^i$$

It will be noted that not only the values of the data codewords **308.1** matter, but also their order. The ordinal placement of the codewords (1^{st}, 2^{nd}, 3^{rd}, etc.) in the

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polynomial maps to the physical ordering of the data codewords **308.1** in the machine-readable symbol **102**.

If the machine-readable symbol **102** is damaged or corrupted, this may result in data codewords **308.1** which are incorrect. The erroneous data can be understood as a received polynomial r(x):

$$r(x) = s(x) + e(x)$$

$$e(x) = \sum_{i=0}^{n-1} e_i x^i$$

where e_i is the coefficient for the i^{th} power of x. Coefficient e_i will be zero if there is no error at that power of x (and so no error for the corresponding i^{th} data codeword **308.1** in the symbol **102**); while the coefficient e_i will be nonzero if there is an error. If there are ν errors at distinct powers i_k of x, then:

$$e(x) = \sum_{k=1}^{N} (\mathrm{e\_i}_k)(x^\wedge i_k)$$

The goal of the decoder is to find the number of errors (ν), the positions of the errors (i_k), and the error values at those positions (e_i_k). From those, e(x) can be calculated, and then e(x) can be subtracted from the received r(x) to get the original message s(x).

There are various algorithms which can be employed, as part of the Reed-Solomon scheme, to identify the error positions (i_k) and the error values at those positions (e_i_k), based solely on the received data codewords **308.1** and the received EC codewords **308.2**. The processes involved, however, are generally a two-stage processes, where:

Stage (I) Error Locations:

The first calculation stage entails identifying the location of the errors. This entails first calculating an error-locator polynomial Λ, and based on Λ, calculating the non-zero error positions i_k. This stage also determines the number of errors (ν). This first stage calculation inevitably requires the use of some of the EC codewords **308.2** in the symbol **102**.

Stage (II) Corrected Values:

Employing the location errors i_k as calculated in stage (i), the second calculation stage identifies the correct values (e_i_k) associated with each error location.

It will be seen then that in the prior art, correcting errors is a two-stage process, where identifying error locations generally precedes, and is an input to, identifying the corrected data at each location. It is a goal of the present system and method to either reduce or possibly eliminate the calculations of stage (I), by using analyses apart from Reed-Solomon error correction to determine identify or mark the erroneous data codewords **308.1**.

Persons skilled in the art will recognize that the non-zero error positions i_k calculated via the alternative methods (discussed further below) can be input directly into stage (II), thereby enabling the calculations of the correct data values in stage (II).

Importantly, in the mathematics of standard Reed-Solomon error correction, errors (both location and data unknown) requires the use of two error correcting code words to repair a damaged codeword. If, on the other hand, knowledge of the location of the error exists, then the error is considered an erasure, and only one error correction codeword is required to repair the erased codeword.

Stated another way: Normally, error-correction in 2D matrix symbologies is used to correct codewords which are errors, meaning that both the location and contents of the codeword are unknown. The goal of the present system and method is to independently flag errors so that they are instead treated as erasures, for which the location is known, thereby requiring only one EC codeword for correction.

Optical Clarity and Optical Ambiguity, Decoding Disadvantage, and Reed-Solomon Error Correction

As discussed above, Reed-Solomon error correction requires the use of two EC codewords **308.2** to correctly recover both the location and the data contents of a single data codeword **308.1** which is flawed. However, the present system and method aims to enable the identification (at least provisionally) of the locations of the flawed or damaged codewords **308**.F—and to make such identification independently of the EC codewords **308.2** in the symbol **102**. Such alternative means of locating the data codewords **308.1** which are flawed supplements the data in the EC codewords **308.2**; as a result, only a single EC codeword **308.2** is required to identify the data in a data codeword **308.1** Flawed codewords **308**.F may also be referred to as codewords which have a "decoding disadvantage."

To identify the locations of the codewords with a decoding disadvantage, independent of the error-correcting information within the symbol **102** itself, the present system and method identifies those codewords **308** in the symbol **102** which have a low level of optical clarity, or equivalently, a high level of optical ambiguity. By "optical clarity" is meant any codeword **308** which, as presented to the reader **100**, is sufficiently clear and distinct (e.g., has high optical contrast) to be read very reliably by the symbol reader's optical system **230**, **235**. If a codeword **308** is not optically clear—for example, due to poor printing, smudging or marking in the field, ripping or tearing, or other causes—then the codeword is deemed optically ambiguous; there is a significant probability that the data for an optically ambiguous codeword, as determined by a reader **100**, will not match the intended data of the same codeword.

FIG. **5** presents a flow-chart of an exemplary method **500** for optically enhanced Reed-Solomon error-correction for a symbol **102**. The steps of exemplary method **500** are generally performed via the processor(s) **240**, memory **245**, and other components of the symbol reader **100**.

In step **505**, the symbol reader **100** identifies the location of the symbol **102** and the appropriate parameters such as the size. For example, for a DataMatrix symbol, the reader **100** finds the "L-shape" **302** and finds the clock track **304** to identify the number of rows and columns in the symbol. The L-shape **302** and clock track **304** help the reader **100** determine the symbol's tilt and orientation, and provide reference points from which to decode the matrix of data cells.

In step **510**, the symbol reader **100** creates a matrix or array of sample points (pixels), indicating the reflectances (bright or dark) of points within the symbol **102**. These sample points are used to determine reflectance of cells **306** within the symbol. A single cell **306** may have multiple sample points measured, and together these may be used (for example, averaged) to determine the reflectance of each cell **306**.

As discussed above, the symbol **102** is composed of codewords **308** with standardized positions, that is, which are made up of standardized clusters of cells **306** with designated positions within the symbol matrix **102**.

In step **515**, the method **500** determines a level of optical clarity for each codeword **308**. A high level of optical clarity, which is desirable, means the codeword's cells are distinctive and that the data value of the codeword can be read with a high probability of accuracy.

A low level of optical clarity—or equivalently, a high level of optical ambiguity—may result from physical damage to a symbol, or from dirt or grease marking the symbol, or other causes as discussed above. Low optical clarity, or high optical ambiguity, means that the codeword's cells are not distinctive and the codeword has a decoding disadvantage. The low level of optical clarity therefore means that the data value of the codeword can be ascertained only with a suboptimal degree of reliability.

Optical clarity/ambiguity may be determined in a variety of ways. In one embodiment of the present system and method, discussed in detail below, the optical clarity/ambiguity is determined based on an analysis of the contrast level between cells **306** within each codeword **308**. Codewords **306** which exhibit the lowest internal contrast levels may be marked as optically ambiguous.

In an alternative embodiment, optical clarity/ambiguity may be determined based on analysis of the degree to which a codeword **308** is in-focus or not in-focus. In an alternative embodiment, optical clarity/ambiguity may be determined based on analysis of the definition or lack of definition of lines separating the dark cells **306** from light cells **306**.

In an alternative embodiment, optical clarity/ambiguity may be determined based on a degree to which the horizontal and vertical lines of the codewords **308** are parallel to, or are not parallel to, the border-L shape. Other methods of assessing optical clarity of a codeword **308** may be envisioned as well, and fall within the scope and spirit of the present system and method.

In step **520**, exemplary method **500** ranks the codewords **308** according to optical clarity, for example from highest to lowest in optical clarity. In step **525**, method **500** identifies the lowest ranked codewords (those which are most optically ambiguous), up to the number of codewords **308** to be used as erasures.

In steps **530** and **535**, the lowest-ranked codewords **308** identified in step **525**—that is, the codewords with the highest optical ambiguity—are marked as erasures in the error-correction equations, and the Reed-Solomon error-correction equations are then executed. Steps **530** and **535** thereby reduce or eliminate the calculations discussed above for a phase (I) of the Reed-Solomon error correction process, and thereby also reduce or eliminate the use of EC codewords **308.2** to identify the locations of flawed codewords **308**.F.

Gray-Scale Contrast Analysis Algorithm

In one embodiment, the present system and method identifies codewords **308** with high optical ambiguity (low optical clarity) via contrast analysis of the codewords within the symbol **102**.

The present system and method employs a "matrix-cell contrast analysis algorithm," "gray-scale contrast analysis algorithm," or simply "contrast analysis algorithm" (CAA) for short. The contrast analysis algorithm of the present system and method determines the actual gray level of each cell **306** in the symbol **102**. The CAA also identifies the black/white contrast threshold for the symbol **102**. The black/white contrast threshold is the brightness level above which a cell **306** is considered to be white, and below which a cell is considered to be black. The algorithm then determines the difference between the contrast level of each cell **306** and the black/white threshold. If the differential is comparatively low for one or more cells **306** in a particular codeword **308**, the codeword **306** may have a decoding disadvantage.

More generally, the CAA may identify a light/dark threshold level, which is a brightness level above which a cell **306** is considered to be of a first, lighter color (for example, white); and below which a cell is considered to be of a second, darker color (for example, black).

A scanner **100** will conventionally store, in memory **245**, the "color" of each cell **306**, for example, a red-green-blue (RGB) value or a hue-saturation-brightness (HSB) value. The present system and method will also store, in the memory (**245**) of the scanner **100**, an actual, measured gray-scale level for each cell **306**.

FIG. **6** presents a flow-chart of an exemplary method **600** for contrast analysis according to the present system and method. Steps **605** through **645** of exemplary method **600** collectively may be considered to be one exemplary embodiments of step **515** of method **500**, already discussed above. (Step **515** determines an optical clarity for each codeword **308** in the symbol **102**.) Step **650** of exemplary method **600** may be considered to be one exemplary embodiment of step **520** of method **500**, that is, ranking the codewords for optical clarity.

Where exemplary method **500** was directed to generally determining and ranking codewords **308** by optical clarity, the exemplary method **600** particularly employs an exemplary approach to contrast analysis in order to determine and rank optical clarity. The steps of exemplary method **600** are generally performed via the processor(s) **240**, memory **245**, and other components of the symbol reader **100**.

In step **605**, the symbol reader **100** determines a local black/white contrast threshold (BWCT). The black/white contrast threshold (BWCT), as described above, is a reflectance level above which a cell **306** is considered white, and below which a cell **306** is considered black. This is typically determined by (i) identifying the reflectance of all the cells **306** in the symbol; (ii) identifying the highest reflectance value and the lowest reflectance value; and (iii) identifying a middle-value, such as the mean or the median, and using the middle-value as the BWCT. The present system and method refines this by employing a local BWCT for each cell **306**. In an exemplary embodiment, a local BWCT for a given cell **306** may be determined by considering only those other cells local to the given cell **306**, and then identifying the mean or median reflectance among those cells. In an embodiment, the number of local cells used to determine the local BWCT may be twenty (20). In an alternative embodiment the number of local cells used to determine the BWCT for a given cell may be higher or lower than twenty (20).

In step **610**, the method **600** selects a particular codeword **308**, (as specified in the appropriate standards for the size and shape of the symbol **102**), and identifies the contrast level (the grayscale level) of each cell in the codeword.

In step **615**, the method **600** determines, for the particular codeword at hand, a bar cell (**306**.B) with a contrast value closest to the BWCT; and a space cell (**306**.S) with a contrast value closest to the BWCT; and then stores these two cell contrast values in a codeword contrast values array in memory (see FIG. **7** below for an example). The contrast values may be labeled as RSmin for the space cell (**306**.S) closest to the BWCT, and RBmax for the bar cell (**306**.B) closest to the BWCT. An equivalent phrasing: RSmin is the smallest space cell reflectance (darkest), and RBmax is the largest bar cell reflectance (lightest).

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Steps **610** and **615** are repeated for all codewords **308** in the symbol **102**. This results in a listing of RSmin and RBmax for each codeword **308** in the symbol.

In step **620**, the method **600** determines the erasure gap for spaces between RSmin and the local black/white contrast threshold for each codeword. (ESgap=RSmin−localBWCT)

In step **625**, the method **600** determines the erasure gap for bars between RBmax and the local black/white contrast threshold for each codeword. (EBgap=localBWCT−RBmax)

In step **630**, the method **600** identifies the largest space cell value in the entire array, that is the largest value for RSmin. This value, which may be labeled as RSmm, is used for normalization in the following step.

In step **635**, the method **600** divides all space gap value entries (ESgap) by the largest space cell ("white cell") value in the array, RSmm, generating an Sgap % value for each codeword. (Sgap %=ESgap/RSmm)

In step **640**, the method **600** identifies the largest bar cell ("black cell") value in the entire array, that is the largest value for RBmin. This value, which may be labeled as RBmm, is used for normalization in the following step.

In step **645**, the method **600** divides all bar gap value entries (EBgap) by the largest bar cell value in the array, RBmm, generating a Bgap % value for each codeword. (Bgap %=EBgap/RBmm)

Sgap % and Bgap %, then, are the percentage relative closeness of the deviant cell to the black/white contrast threshold. These percentage values, Sgap % and Bgap %, may also be referred to as the minimum interior contrast levels **702** for each cell **306**. The minimum interior contrast levels **702** are a measure of the optical clarity of the codewords **308** in the symbol **102**. Specifically: Those codewords **308** with the lowest values for Sgap % and/or the lowest values for Bgap % have the highest optical ambiguity (and therefore the least or worst optical clarity).

As noted above, the preceding steps **605** through **645** of method **600** may collectively be considered to be one exemplary embodiment of step **515** of method **500**, already discussed above, that is, determining an optical clarity for each codeword **308** in the symbol **102**.

In step **650**, and based on the Sgap % and Bgap % values determined in steps **635** and **645**, the method **600** ranks the lowest gap percent values up to the number of error correction codewords to be used as erasures. Step **650** of exemplary method **600** may be considered to be one exemplary embodiment of step **520** of method **500**, that is, ranking the codewords for optical clarity/ambiguity.

These lowest ranked, least clear codewords are the codewords with the lowest optical clarity (or highest ambiguity), which are then used as erasures in the Reed-Solomon equations (step **530** of method **500**).

Sample Applications

FIG. **7** presents an exemplary codeword contrast values array **700** of the kind which may be constructed according to exemplary method **600**, above. The array contains actual codeword measurements for the symbol image **102**.D1/**102**.D2 of FIG. **4**, above. In array **700**, CW is the codeword number; and, as per discussion above:

- RSmin is the smallest (darkest) space cell reflectance for each codeword **308**;
- RBmax is the largest (lightest) bar cell reflectance for each codeword **308**;
- ESgap is the erasure space gap calculated as RSmin minus the threshold (75 hex in this case);
- EBgap is the threshold minus RBmax for the bar cells;
- Sgap % and Bgap % are the relative closeness of the deviant cell to the black/white threshold in percent, also referred to as the minimum interior contrast levels **702**; and
- Rank is a listing of the worst **12** codewords (those with the smallest gap percentage) in the symbol **102**.

FIG. **8** illustrates an exemplary case-analysis demonstrating how poor cell contrast can identify a majority of flawed codewords **308**.F. The damaged symbols shown in the figure are the same as the damaged symbol pictured and illustrated in FIG. **4**, above. In FIG. **8**, numbered codeword locations **805** are identified (by a standardized number scheme) for those codewords which are flowed or damaged.

102.D2, reproduced here from FIG. **4** for convenience, is the damaged symbol as it was interpreted by an actual scanner **100** in the field.

Symbol **102**.D3 is the same symbol as it was interpreted according the exemplary contrast analysis algorithms discussed above in conjunction with FIG. **5** and FIG. **6**.

As can be seen in FIG. **8**, there are two codewords **815** which were assessed as being in error by the present system and method, but which were actually read correctly by the scanner **100**. Of the latter codewords, one was in the damaged region **402** (codeword **27**) and another was a codeword where there is a scratch through the dark cell, making it lighter (codeword **22**).

As can also be seen from FIG. **8**, there is one codeword **810** which was actually read in error by the scanner **100**, but was not flagged by the gray-scale contrast analysis algorithm of the present system and method.

All the remaining, identified codewords **308** (a total of ten) which were flagged as being in error based on contrast analysis are codewords which were, in fact, read in error by the scanner **100**.

The codeword that the analysis missed (codeword **27**) is easily decoded using the 6 error correction codewords still remaining. This is an example of a symbol that was far from being decodable using standard decoding methods, yet using a gray-scale contrast analysis algorithm, the symbol can sustain this and slightly more damage and still be decodable.

Further Applications

The example shown (in FIGS. **4** and **8**) clearly benefits from the gray-scale contrast analysis decoding since the damage to the symbol **102**.D**1**/**102**.D**2** is contrast based. However, the present system and method will also work with other types of damage such as matrix distortion, uniform dark or light damage and for DPM cell variation. When these types of distortion are present, there will be many sample points that rest on cell boundaries which will be recorded as reduced contrast values. As long as the matrix distortion (such as wrinkling) is localized or the dark/light damage is less than approximately one-third of the symbol, the present system and method will substantially improve decoding rates on all types of problem symbols **102**.D.

Summary

Improved matrix symbology decode performance is possible when there is some knowledge of potentially damaged codewords **308**. One means of achieving improved decode performance is by measuring the gray-level contrast variation of every codeword, and marking those with contrast values that are closest to the black/white threshold as erasures. Using gray-level information and using erasure correction in matrix symbologies will allow successful decoding far into a damage region where current product decoding fails.

To supplement the present disclosure, this application incorporates entirely by reference the following patents, patent application publications, and patent applications:

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In the specification and/or figures, typical embodiments of the invention have been disclosed. The present invention is not limited to such exemplary embodiments. The use of the term "and/or" includes any and all combinations of one or more of the associated listed items. The figures are schematic representations and so are not necessarily drawn to scale. Unless otherwise noted, specific terms have been used in a generic and descriptive sense and not for purposes of limitation.

The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flow charts, schematics, exemplary data structures, and examples. Insofar as such block diagrams, flow charts, schematics, exemplary data structures, and examples contain one or more functions and/or operations, it will be understood by those skilled in the art that each function and/or operation within such block diagrams, flowcharts, schematics, exemplary data structures, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof.

In one embodiment, the present subject matter may be implemented via Application Specific Integrated Circuits (ASICs). However, those skilled in the art will recognize that the embodiments disclosed herein, in whole or in part,

can be equivalently implemented in standard integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more controllers (e.g., microcontrollers) as one or more programs running on one or more processors (e.g., microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of ordinary skill in the art in light of this disclosure.

In addition, those skilled in the art will appreciate that the control mechanisms taught herein are capable of being distributed as a program product in a variety of tangible forms, and that an illustrative embodiment applies equally regardless of the particular type of tangible instruction bearing media used to actually carry out the distribution. Examples of tangible instruction bearing media include, but are not limited to, the following: recordable type media such as floppy disks, hard disk drives, CD ROMs, digital tape, flash drives, and computer memory.

The various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the present systems and methods in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims, but should be construed to include all machine-readable symbol scanning and processing systems and methods that read in accordance with the claims. Accordingly, the invention is not limited by the disclosure, but instead its scope is to be determined entirely by the following claims.

What is claimed is:

1. A method of error correction for a two-dimensional (2D) symbol designed for optical reading by a symbol reader, the symbol having a plurality of cells of a designated first color comprising first color cells and a designated second color comprising second color cells which cells are arranged in a two-dimensional matrix; the symbol further having a plurality of codewords at specified locations within the symbol, each codeword comprising at least one specified group of cells; the method comprising:

optically reading, by an optical scanner of the symbol reader, the plurality of codewords in the symbol, the plurality of codewords comprising a first plurality of data codewords storing data indicated by a pattern of the first and second color cells in the codeword, and a second plurality of error-correction (EC) codewords derived from the data codewords and providing redundancy for the data represented by the data codewords;

determining, via a hardware processor of the symbol reader, a location for a data codeword of the first plurality of data codewords which is optically ambiguous, the determining comprising

selecting the data codeword based on a standards-established set of codeword locations within the symbol; and

then performing a contrast analysis on the selected data codeword, wherein the contrast analysis identifies a minimum interior contrast level for the selected data codeword, and the performing of the contrast analysis comprises

determining reflectance of first color cells of the first plurality of cells of the selected data codeword, and

determining reflectance of second color cells of the second plurality of cells of the selected data codeword;

identifying a respective minimum interior contrast level for each codeword in the symbol; and

flagging as optically ambiguous a plurality of codewords with the lowest minimum interior contrast levels among all the codewords in the symbol, up to a specified number of codewords;

marking via the hardware processor, in an error correction (EC) equation stored in a memory of the symbol reader, the location of the optically ambiguous data codeword within the symbol; and

executing, via the hardware processor, the EC equation to correct errors in the read plurality of codewords.

2. The method of claim **1**, wherein determining the location for the data codeword which is optically ambiguous comprises:

determining that the selected data codeword displays a level of contrast between the first color cells and the second color cells which is insufficient for an unambiguous decoding of the selected data codeword by the symbol reader.

3. The method of claim **1**, wherein performing the contrast analysis on the selected data codeword comprises:

(i) determining a dark/light threshold level, wherein the dark/light threshold level is indicative of a reflectance above which a cell is assessed as being of the first color and below which a cell is assessed as being of the second color;

(ii) determining a level of difference between the reflectance of each cell of the selected data codeword and the dark/light threshold level; and

(iii) determining the minimum interior contrast level for the selected data codeword by determining, among all the cells within the selected data codeword, a specific cell with a lowest level of difference between the reflectance of the specific cell and the dark/light threshold level.

4. The method of claim **3**, further comprising:

ranking each codeword of the symbol for a respective level of optical ambiguity, wherein each codeword is ranked for its respective level of optical ambiguity based on the minimum interior contrast level of that codeword as compared with the minimum interior contrast levels of all the other codewords in the symbol, wherein:

a first minimum interior contrast level of a first codeword is compared with a second minimum interior contrast level of a second codeword, the codeword of the two with the lower minimum interior contrast level being assigned a higher level of optical ambiguity.

5. The method of claim **3**, further comprising:

(i) determining a local dark/light threshold level for a specific cell, wherein the local dark/light threshold level for the specific cell is determined based on a plurality of cells local to the specific cell;

(ii) determining a level of difference between the reflectance of each cell of the selected data codeword and each cell's local dark/light threshold level; and

(iii) determining the minimum interior contrast level for the selected data codeword by determining, among all the cells within the selected data codeword, a specific cell with a lowest level of difference between the reflectance of the specific cell and the cell's local dark/light threshold level.

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6. An electronic system that acquires a machine-readable two-dimensional (2D) symbol designed for optical reading by the system, the symbol having a plurality of cells of a designated first color comprising first color cells and a designated second color comprising second color cells which cells are arranged in a two-dimensional matrix; the symbol further having a plurality of codewords at specified locations within the symbol, each codeword comprising at least one specified group of cells; the plurality of codewords comprising a first plurality of data codewords storing data indicated by a pattern of the first and second color cells in the codeword, and a second plurality of error-correction (EC) codewords derived from the data codewords and providing redundancy for the data represented by the data codewords, the electronic system comprising:

an optical scanner configured to optically receive the plurality of cells in the symbol and to convert the cell pattern of the symbol into an electrical pattern subject to electronic storage and computational analysis;

a memory configured to store the electrical pattern of the symbol, and an error-correction (EC) equation; and

a hardware processor which is configured to:

determine a location for a data codeword of the first plurality of data codewords which is optically ambiguous, comprising the hardware processor being configured to determine the location for the data codeword which is optically ambiguous by

selecting the data codeword based on a standards-established set of codeword locations within the symbol, said standards-established set being stored in the memory of the electronic system, and

then performing a contrast analysis on the selected data codeword, wherein the contrast analysis identifies a minimum interior contrast level for the selected data codeword, and the performing of the contrast analysis comprises

determining reflectance of first color cells of the first plurality of cells of the selected data codeword, and

determining reflectance of second color cells of the second plurality of cells of the selected data codeword;

identify a respective minimum interior contrast level for each codeword in the symbol;

flag as optically ambiguous a plurality of codewords with the lowest minimum interior contrast levels among all the codewords in the symbol, up to a specified number of codewords;

mark in the error correction equation the location of the optically ambiguous data codeword within the symbol; and

execute the EC equation to correct errors in the read plurality of codewords.

7. The electronic system of claim 6, wherein the hardware processor is further configured to determine the location for the data codeword which is optically ambiguous by:

determining that the selected data codeword displays a level of contrast between the first color and the second color which is insufficient for an unambiguous decoding of the selected data codeword by the electronic system.

8. The electronic system of claim 6, wherein to perform the contrast analysis on the selected data codeword the hardware processor is further configured to:

(i) determine a dark/light threshold level, wherein the dark/light threshold level is indicative of a reflectance above which a cell is assessed as being of the first color and below which a cell is assessed as being of the second color;

(ii) determine a level of difference between the reflectance of each cell of the selected data codeword and the dark/light threshold level; and

(iii) determine the minimum interior contrast level for the selected data codeword by determining, among all the cells within the selected data codeword, a specific cell with a lowest level of difference between the reflectance of the specific cell and the dark/light threshold level.

9. The electronic system of claim 8, wherein the hardware processor is further configured to:

rank each codeword of the symbol for a level of optical ambiguity, wherein each codeword of the symbol is ranked for the level of optical ambiguity based on the minimum interior contrast level of that codeword as compared with the minimum interior contrast levels of all the other codewords in the symbol, wherein:

a first minimum interior contrast level of a first codeword is compared with a second minimum interior contrast level of a second codeword, the codeword of the two with the lower minimum interior contrast level being assigned a higher level of optical ambiguity.

10. The electronic system of claim 8, wherein the hardware processor is further configured to:

(i) determine a local dark/light threshold level for a specific cell, wherein the local dark/light threshold level for the specific cell is determined based on a plurality of cells local to the specific cell;

(ii) determine a level of difference between the reflectance of each cell of the data codeword and each cell's local dark/light threshold level; and

(iii) determine the minimum interior contrast level for the data codeword by determining, among all the cells within the data codeword, a specific cell with a lowest level of difference between the reflectance of the specific cell and the cell's local dark/light threshold level.

11. The electronic system of claim 6, wherein the error-correction equation stored in the memory comprises Reed-Solomon error correction equations.

12. A computer-readable, non-transitory storage medium storing instructions that, when executed by a hardware processor of a symbol reader, causes the hardware processor to execute a method of error correction for a two-dimensional (2D) symbol designed for optical reading by the symbol reader, the symbol having a plurality of cells of a designated first color comprising first color cells and a designated second color comprising second color cells which cells are arranged in a two-dimensional matrix; the symbol further having a plurality of codewords at specified locations within the symbol, each codeword comprising at least one specified group of cells; the plurality of codewords comprising a first plurality of data codewords storing data indicated by a pattern of the first and second color cells in the codeword, and a second plurality of error-correction (EC) codewords derived from the data codewords and providing redundancy for the data represented by the data codewords; the method comprising:

optically reading, by an optical scanner of the symbol reader, the plurality of codewords in the symbol;

determining a location for a data codeword of the first plurality of data codewords which is optically ambiguous, the determining comprising

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selecting the data codeword based on a standards-established set of codeword locations within the symbol; and

then performing a contrast analysis on the selected data codeword, wherein the contrast analysis identifies a minimum interior contrast level for the selected data codeword, and the performing of the contrast analysis comprises

determining reflectance of first color cells of the first plurality of cells of the selected data codeword, and

determining reflectance of second color cells of the second plurality of cells of the selected data codeword;

identifying a respective minimum interior contrast level for each codeword in the symbol;

flagging as optically ambiguous a plurality of codewords with the lowest minimum interior contrast levels among all the codewords in the symbol, up to a specified number of codewords;

marking in an error correction (EC) equation the location of the optically ambiguous data codeword within the symbol; and

executing the EC equation to correct errors in the read plurality of codewords.

13. The computer-readable, non-transitory storage medium of claim **12**, wherein determining the location for the data codeword which is optically ambiguous comprises:

determining that the selected data codeword displays a level of contrast between the first color and the second color which is insufficient for an unambiguous decoding of the selected data codeword by the symbol reader.

14. The computer-readable, non-transitory storage medium of claim **12**, wherein performing the contrast analysis on the selected data codeword comprises:

(i) determining a dark/light threshold level, wherein the dark/light threshold level is indicative of a reflectance above which a cell is assessed as being of the first color and below which a cell is assessed as being of the second color;

(ii) determining a level of difference between the reflectance of each cell of the selected data codeword and the dark/light threshold level; and

(iii) determining the minimum interior contrast level for the selected data codeword by determining, among all the cells within the selected data codeword, a specific cell with a lowest level of difference between the reflectance of the specific cell and the dark/light threshold level.

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(12) **United States Patent**
Wang

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(54) **LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD**

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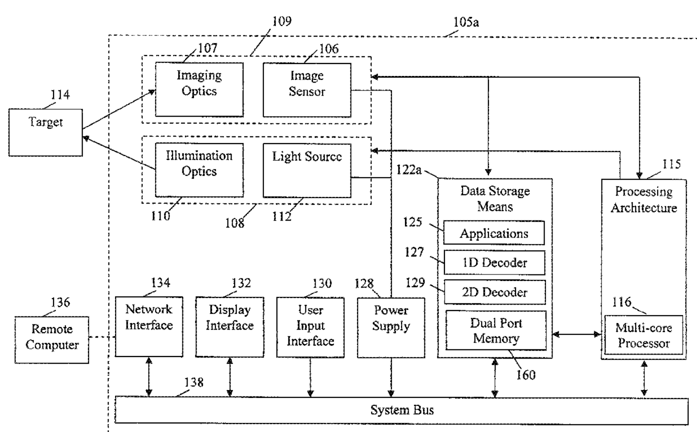
(57) **ABSTRACT**

A portable data terminal including a multi-core processor having at least a first core and a second core, at least one illumination assembly and at least one imaging assembly and data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder.

19 Claims, 5 Drawing Sheets



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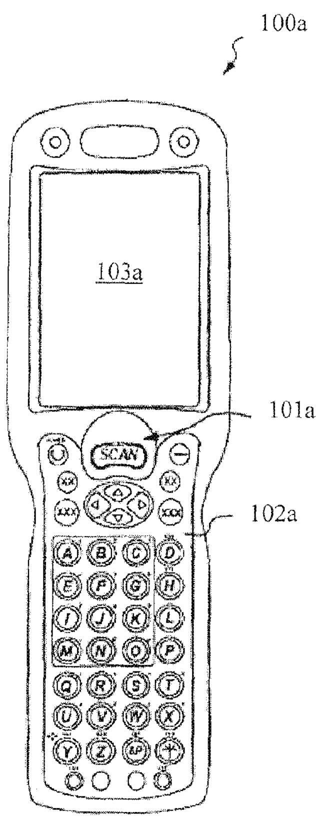


Fig. 1A

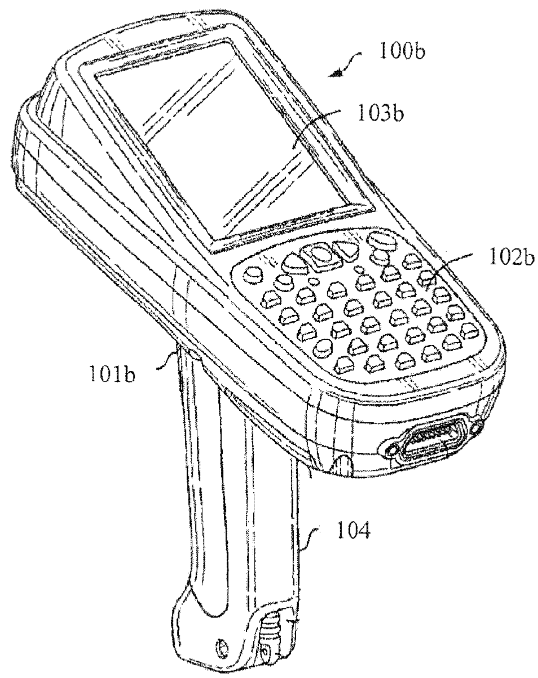
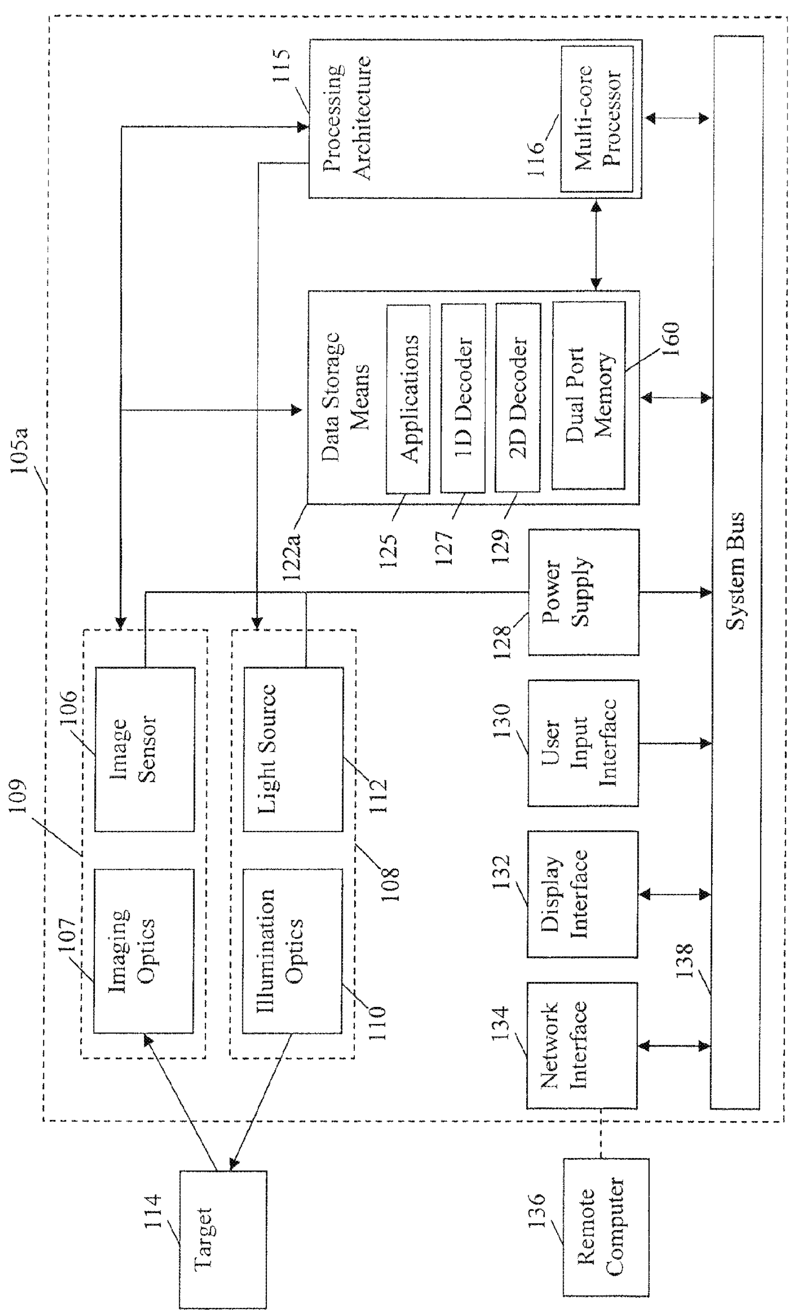


Fig. 1B

PX-225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116
Multi-core Processor
Data Storage Means
Applications
1D Decoder
2D Decoder
Dual Port Memory
160
122a
125
127
129
System Bus
109
106
Image Sensor
107
Imaging Optics
Light Source
112
Illumination Optics
108
110
128
Power Supply
130
User Input Interface
132
Display Interface
134
Network Interface
138
114
Target
136
Remote Computer

FIG. 2a

PX-225

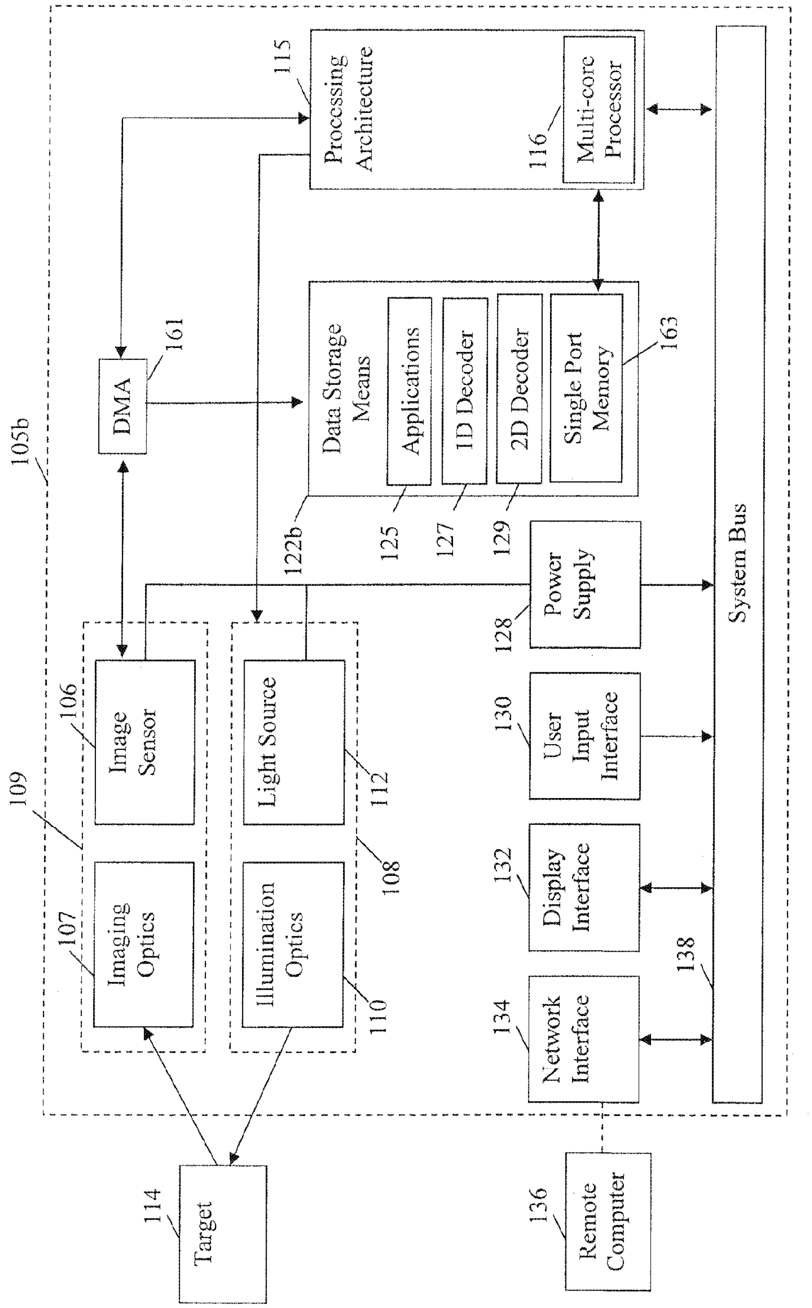
105b
Processing Architecture
115
116
Multi-core Processor
DMA
161
Data Storage Means
Applications
1D Decoder
2D Decoder
Single Port Memory
163
122b
125
127
129
Power Supply
128
System Bus
Image Sensor
106
Light Source
112
109
Imaging Optics
107
Illumination Optics
108
110
User Input Interface
130
Display Interface
132
Network Interface
134
138
Target
114
Remote Computer
136

FIG. 2b

PX-225

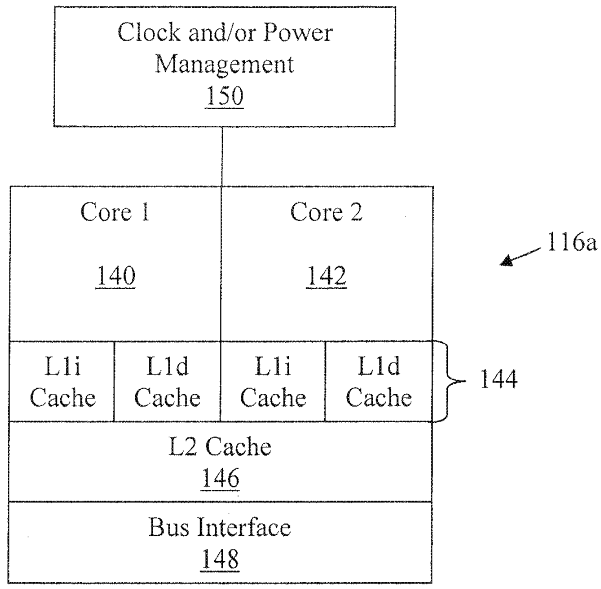

FIG. 3

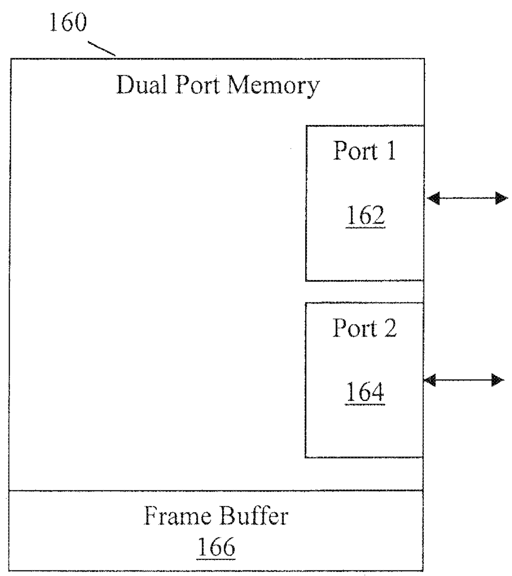

FIG. 4

PX-225

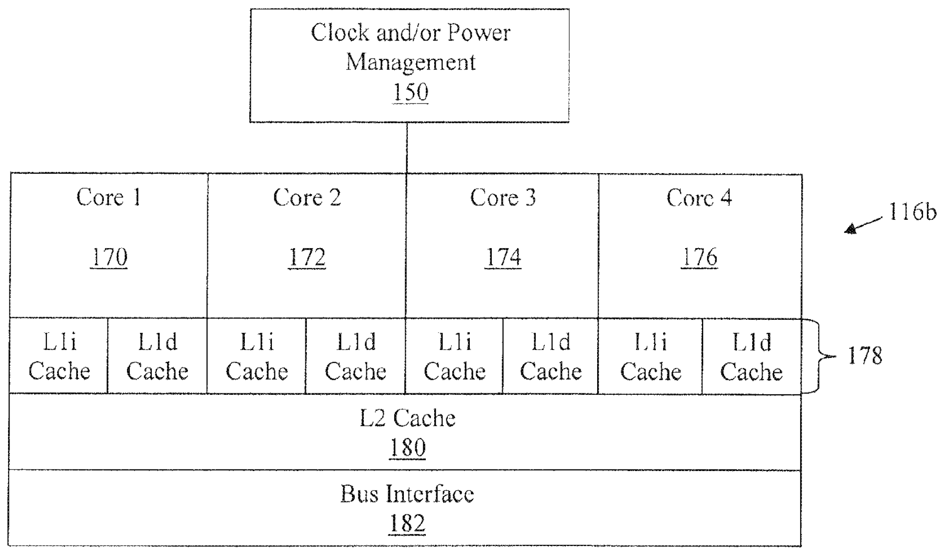
Clock and/or Power
Management
150
Core 1
170
Core 2
172
Core 3
174
Core 4
176
116b
L1i
Cache
L1d
Cache
L1i
Cache
L1d
Cache
L1i
Cache
L1d
Cache
L1i
Cache
L1d
Cache
178
L2 Cache
180
Bus Interface
182

FIG. 5

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LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD

TECHNICAL FIELD

The present invention relates to portable data terminals and more particularly, to portable data terminals configured to capture an image and decode any bar code contained in the image.

BACKGROUND INFORMATION

Portable data terminals (PDTs) such as laser indicia reading devices, optical indicia reading devices, barcode scanners and barcode readers, for example, typically read data represented by printed indicia such as symbols, symbology, and bar codes, for example. One type of symbol is an array of rectangular bars and spaces that are arranged in a specific way to represent elements of data in machine readable form. Optical indicia reading devices typically transmit light onto a symbol and receive light scattered and/or reflected back from a bar code symbol or indicia. The received light is interpreted by an image processor to extract the data represented by the symbol. Laser indicia reading devices typically utilize transmitted laser light. One-dimensional (1D) optical bar code readers are characterized by reading data that is encoded along a single axis, in the widths of bars and spaces, so that such symbols can be read from a single scan along that axis, provided that the symbol is imaged with a sufficiently high resolution.

In order to allow the encoding of larger amounts of data in a single bar code symbol, a number of one-dimensional (1D) stacked bar code symbologies have been developed which partition encoded data into multiple rows, each including a respective 1D bar code pattern, all or most all of which must be scanned and decoded, then linked together to form a complete message. Scanning still requires relatively higher resolution in one dimension only, but multiple linear scans are needed to read the whole symbol.

A class of bar code symbologies known as two-dimensional (2D) matrix symbologies have been developed which offer orientation-free scanning and greater data densities and capacities than 1D symbologies. 2D matrix codes encode data as dark or light data elements within a regular polygonal matrix, accompanied by graphical finder, orientation and reference structures.

Conventionally, a PDT includes a central processor which directly controls the operations of the various electrical components housed within the PDT. For example, the central processor controls detection of keypad entries, display features, wireless communication functions, trigger detection, and bar code read and decode functionality. More specifically, the central processor typically communicates with an illumination assembly configured to illuminate a target, such as a bar code, and an imaging assembly configured to receive an image of the target and generate an electric output signal indicative of the data optically encoded therein.

The output signal is generally representative of the pixel data transmitted by an image sensor of the imaging assembly. Because the pixel data may not be high enough quality for the processor to reliably decode the bar code in the image, PDTs generally successively capture images, or image frames, until a reliable decode is complete. Further, where the bar codes being decoded vary from 1D and 2D symbologies, the PDT generally sequentially executes decode algorithms for the multiple symbologies. This process can be time-intensive because the processor must wait for the pixel data to be stored in memory before it can access the data in order to execute a decode algorithm and then must further wait for a decode algorithm to complete before a second decode algorithm can execute. Further, in many settings such as warehouses, shopping centers, shipping centers, and numerous others, PDTs are used to decode bar codes in serial fashion such that a faster decode operation generally increases throughput.

Attempts have been made to increase decode speed particularly by multi-threading. Multi-threading, or hyper-threading, allows multiple threads to use a single processing unit by providing processor cycles to one thread when another thread incurs a latency such as a cache miss, for example, which would cause the processor to incur several cycles of idle time while off-chip memory is accessed. Using multi-threading, the central processor idle time is minimized but not substantially parallelized. Further, context switching between threads can significantly increase overhead, as the state of one process/thread is saved while another is loaded, further minimizing any efficiency gain.

Accordingly, there remains a need in the art for a PDT system architecture that will allow for faster, substantially parallel, bar code decoding operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is disclosed with reference to the accompanying drawings, wherein:

FIG. **1** is a plan view and a side perspective view of two exemplary PDTs.

FIG. **2***a* is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **2***b* is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **3** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

FIG. **4** is a block schematic diagram of an exemplary dual port memory module according to the present invention.

FIG. **5** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

It will be appreciated that for purposes of clarity and where deemed appropriate, reference numerals have been repeated in the figures to indicate corresponding features.

DETAILED DESCRIPTION

Referring to FIGS. **1**A and **1**B, two exemplary PDTs **100** for reading/scanning printed indicia are shown. The PDT housing can be shaped so as to fit comfortably into a human hand using a handle portion **104** and can include a finger actuatable scan/capture or trigger button **101** as well as a keypad **102** for inputting data and commands, power button, and antenna for facilitating communication with a local or remote host processor, for example. The PDT also includes a display **103**, such as an LCD or OLED display, for example, for displaying information to the user. If the display **103** is a touch screen, a stylus (not shown) may also be included to facilitate interaction with the touch screen. An aperture in the housing is included such that the illumination **108** and imaging optics **109** have substantially unobstructed access to the target **114**. The PDT can also include a power port for receiving a power supply as well as one or more communication ports for facilitating wired or wireless communication with a network interface **134**. Although the present invention is described with respect to a PDT, the invention can be utilized in any bar code scanner, mobile device, mobile computer, or personal data assistant, for example.

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Referring to FIG. **2**, there is shown a block schematic diagram of the basic structures that together comprise a PDT **105** according to the present invention. The PDT **105** includes an illumination assembly **108** for illuminating a target **114**, such as a bar code, and an imaging assembly **109** for receiving an image of the target **114** and generating an electric output signal indicative of the pixel data optically encoded therein. The illumination assembly **108** includes at least one light source **112** together with illumination optics **110**, such as one or more reflectors, for directing light from the light source in the direction of the target **114**. The light source **112** can include at least one LED configured to emit light in the near-infrared range and/or at least one LED configured to emit light in the visible range. The imaging assembly **102** includes a 2D image sensor **106**, such as a CCD, CMOS, NMOS, PMOS, CID, or CMD solid state imagine sensor, along with imaging optics **107** for receiving and focusing an image of the target **114** onto the image sensor **106**.

Still referring to FIG. **2**, the PDT **105** further includes a processing architecture **115** which controls the operation of the PDT **105** by implementing program instructions it retrieves from the data storage means **122**. More specifically, the processing architecture **115** is configured to receive, output and process data, including image/pixel data, operate the imaging **109** and illumination **108** assemblies, and communicate with a system bus **138** among other operations. Further, the processing architecture **115** may be configured to control the illumination of the light source **112**, the timing of the image sensor **106**, analog-to-digital conversion, transmission and reception of data to and from a processor of a remote computer **136** external to the reader through a network interface **134**, such as an RS-232, RS-485, USB, Ethernet, Wi-Fi, Bluetooth™, IrDA and Zigbee interface, control a user input interface to manage user interaction with a scan/trigger button **101** and/or keypad **102**, and control an output device **103**, such as an LCD or an OLED display, through the display interface **132**. The processing architecture **115** includes at least one multi-core processor **116** as described in detail below with respect to FIGS. **3** and **5** but optionally can include an additional processor(s) or microprocessor(s) such as VLSI or ASIC integrated circuit microprocessor(s). In one embodiment shown in FIG. **2***a* the data storage means **122***a* includes at least one dual port memory module **160**, such as RAM for example, described in detail below with respect to FIG. **4** but optionally can include additional memory modules such as local, network-accessible, removable and/or non-removable memory, such as RAM, ROM, and/or flash. In another embodiment shown in FIG. **2***b*, the data storage means **122***b* includes at least one single port memory module **163**, such as RAM for example, in communication with a direct memory access (DMA) controller **161** as described further below. The data storage means **122** is shown as including applications **125**, such as an operating system for example, a 1D decoder **127**, and a 2D decoder **129**. The decoders **127** and **129** include program instructions that, when executed by the multi-core processor **116**, retrieve image pixel data and decode any bar code contained in the image as is known in the art. Although the decoders **127** and **129** are shown as separate from the dual port memory **160** in FIG. **2***a*, in another embodiment the decoder **127** and **129** program instructions are stored in the dual port memory **160**. The PDT **105** also includes one or more power supplies **128**, such as one or more batteries and/or circuitry for receiving an alternating current, and a user input interface **130** for receiving data from a user input device **102**, such as a keyboard, keypad, and/or touch screen. The PDT **105** structures shown in FIG. **2** are preferably supported on one or more printed circuit boards (not shown).

Referring to FIG. **3**, a multi-core processor **116** according to the present invention is shown as a dual-core processor **116***a* having a first core **140** and a second core **142**. The cores can also share one cache, or in a multilevel cache architecture, each utilize its own respective cache (e.g. L1) and share another cache (e.g. L2) or any combination thereof. In the embodiment shown in FIG. **3**, a first level of cache **144** is shown as having instruction and data caches for each core **140**, **142** and a second level of cache **146** is shown as being shared among both cores **140** and **142**. The cores **140** and **142** can be integrated on the same integrated circuit die or they can be integrated onto multiple dies in the same integrated circuit package as is known in the art. Further, the processor **116** can also include one or more independent or shared bus interfaces such as a shared bus interface **148** for communication with a system bus and/or the data storage means **122**. Each core **140** and **142** has its own processing unit and is capable of issuing instructions transmitted through the bus interface to a bus as well as simultaneously performing operations.

Referring to one embodiment shown in FIGS. **2***a* and **4**, dual port memory **160** is shown as including a first port **162** and a second port **164**. At least a portion of the dual port memory, identified as frame buffer **166** in FIG. **4**, is configured to store image frame data as received from the image sensor. Dual port memory, such as the dual port memory described by U.S. Pat. No. 5,276,842 to Sugita, incorporated herein by reference, is preferably configured to be accessed by two cores simultaneously on the same clock. Contention issues are preferably handled by arbitration system or arbitration logic as is known in the art and as one exemplary implementation of an arbitration system is also described in the ’842 patent. Dual port memory can also be implemented with a single port memory core as taught by Balasubramanian et al. in U.S. Pat. No. 7,349,285, incorporated herein by reference, whereby access requests are processed on both the high and low logic states of the memory clock cycle.

In an exemplary operation, the processing architecture **115** retrieves program instructions from data storage means **122***a*, over system bus **138**, which the architecture implements to control the illumination assembly **108** to focus light on a target **114** containing a bar code and imaging assembly **109** to receive the reflected light. The image sensor **106** then transmits output signals, representative of pixel data of the captured image, to the first port **162** of the dual port memory **164** where it is stored in a frame buffer **166**. Each of the first core **140** and the second core **142** can then access the frame buffer **166** and retrieve the pixel data. To allow for parallel decoding, the first core **140** can be configured to execute the program instructions of the 1D decoder and the second core **142** can be configured to execute the program instructions of the 2D decoder. Accordingly, whether the image contains a 1D or 2D bar code, decoding can occur at substantially the same time decreasing the time required for a successful decode. Further, image pixel/frame data can be stored in the dual port memory **160** on the same clock cycle as image pixel/frame data is being retrieved by the first core **140** and/or the second core **142**. PDT **105** can be configured to continuously image the target **114** and store the pixel data, or each frame, in the frame buffer and the cores **140** and **142** can continually process the image frame data, in parallel, until a successful decode event occurs. Upon successful decode, the decoded data is optionally transmitted to the data storage means **122** where it can be accessed, for example, by an application **125**.

In another embodiment, the first core is configured to execute 1D decoder **127** program instructions as well as image quality filter program instructions stored in data storage means **122**. When executed by the first core **140**, the

image quality filter program instructions analyze, in real time, the pixel data/each frame retrieved by the core from the frame buffer for quality with respect to contrast, for example. The frame can then be assigned an image quality score which can be factored into a decode algorithm's decision with respect to selecting the highest image quality score frame available in the frame buffer. Further, the image quality filter program instructions can be configured to interrupt an existing decode **127** process which is decoding a frame/image with a low image quality score should a frame/image with a higher image quality score be captured.

In yet another embodiment, the first core **140** is configured to execute image quality filter program instructions, or any other program instructions related to image processing, for example, stored in data storage means **122** and the second core **142** is configured to execute 1D decoder **127** program instructions as well as 2D decoder program instructions **129**.

Referring to FIG. **5**, another embodiment is shown wherein the multi-core processor is a quad-core processor further including a third core and a fourth core as well as a first cache level **178**, a second shared cache level **180** and a bus interface **182**. A quad-core processor **116***b* generally refers to four processing units or cores **170**, **172**, **174** and **176** manufactured on the same integrated circuit. In this embodiment, the third core **174** can be configured to execute the program instructions of the image quality filter and the fourth core **176** can execute program instructions related to communication with the network interface **134**. Accordingly, the user does not have to wait to pull the trigger or press the scan button again until the first or second core has executed communication routines to transmit the decode results, for example through the network interface **134** to a remote computer **136**, because the fourth core **176** can handle communication with the network interface **134** in parallel with the first and/or second core causing the PDT **105** to capture a new image and begin a new process of decoding any bar code contained in the image.

Referring to FIG. **2***b*, although the invention has thus far been described as including a dual port memory module, in another embodiment the data storage means **122***b* includes a single port memory **163** configured to store a frame buffer. In this embodiment, preferably a DMA controller **161** is included as being in communication with the imaging assembly **109**, the processing architecture **115** and the data storage means **122***b*. The DMA controller **161** can off-load the processor by transferring pixel data from the image sensor **106** directly to the single port memory **163** without involving the processing architecture **115** including the multi-core processor **116**. Accordingly, processor cycles that otherwise would be used to manage a frame buffer can instead be used to run decode **127**, **129** algorithms and/or otherwise as described above,

While the present invention substantially reduces the time required for a successful decode, it can also effectively manage the system clock and/or the power supplied to each core to reduce overall power consumption. Particularly in PDTs that are mostly powered by battery, power consumption is a concern because the greater the power dissipated, the faster the remaining battery life is reduced. Accordingly, and as shown in FIGS. **3** and **5**, a clock management module/logic **150** configured to dynamically vary the clock speed received by each respective core based on the workload/utilization of each core and/or a power management module/logic **150** configured to dynamically vary the voltage received by at least a portion of each core can be utilized to manage resources consumed by the multi-core processor **116***b*. One method of power management is described in U.S. patent application Ser. No. 11/238,489 to Borkar et al., incorporated herein by reference, as including voltage regulators to supply power to each core or a part of a core depending on a number of factors including activity, core temperature, transient current consumption, and reliability. Another method of power management has been described by Kim in U.S. patent application Ser. No. 11/424,080, incorporated herein by reference, which includes modulating the mode of the processor to single core or multi-core depending on a number of factors including whether the PDT is connected to AC or battery power, remaining battery level, available memory, and memory usage. One exemplary clock management module is disclosed by Naveh et al. in U.S. patent application Ser. No. 10/899,674, incorporated herein by reference, wherein the clock management module utilizes independent clock throttle settings for each core, independent clock throttle of various functional blocks of one or more core's internal architecture such as reorder buffers and reservation station tables, for example, and scaling the clock frequency of the bus that the multi-core processor uses to communicate with system components.

While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims.

What is claimed is:

1. A portable data terminal, comprising:

a multi-core processor having at least a first core and a second core;

at least one illumination assembly and at least one imaging assembly; and

data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder; and

wherein the first core of the multi-core processor executes the one-dimensional decoder and the second core executes the two-dimensional decoder

wherein the one-dimensional decoder and two-dimensional decoder run synchronously in parallel.

2. The portable data terminal of claim **1**, wherein the data storage means further includes at least one multi-port memory module having at least a first port and a second port, the at least one multi-port memory module being configured to receive output signals from the imaging assembly and communicate with the multi-core processor.

3. The portable data terminal of claim **2**, wherein the imaging assembly further includes imaging optics and an image sensor and the illumination assembly further includes illumination optics and at least one light source.

4. The portable data terminal of claim **3**, wherein the first port is configured to receive at least one output signal from the imaging assembly, the output signals representing pixel data transmitted by the image sensor, and the second port is configured to communicate with the multi-core processor.

5. The portable data terminal of claim **4**, wherein the receipt of the at least one output signals and the communication with the multi-core processor both occur on the same clock cycle.

6. The portable data terminal of claim **1**, further including a power supply, at least one system bus, a network interface, a display interface, and a user input interface.

7. The portable data terminal of claim **1** further including at least one management module selected from the group consisting of a clock management module configured to dynamically vary the clock speed received by each respective core based on the workload of each core and a power management module configured to dynamically vary the voltage received by at least a portion of each core.

8. The portable data terminal of claim **1**, wherein the multi-core processor further includes a bus interface and at least one level of cache.

9. The portable data terminal of claim **1**, further including a first level of cache and a second level of cache, the first level including an instruction cache and a data cache for each core and the second level being shared among all the cores.

10. The portable data terminal of claim **1**, wherein the multi-core processor further includes a third core and a fourth core.

11. The portable data terminal of claim **10**, wherein the program instructions stored in the data storage means further includes an image quality filter.

12. The portable data terminal of claim **11**, further including a network interface selected from the group consisting of RS-232, RS-485, USB, Ethernet, Wi-Fi, IrDA and Zigbee.

13. The portable data terminal of claim **12**, wherein the third core of the multi-core processor executes the image quality filter and the fourth core of the multi-core processor communicates with the network interface.

14. The portable data terminal of claim **1**, further including a direct memory access controller in communication with the imaging assembly, multi-core processor and data storage means and wherein the data storage means further includes at least one single port memory module.

15. A method of decoding a bar code, comprising:

providing a portable data terminal having a multi-port memory and a multi-core processor;

capturing an image of a target;

transferring image pixel data to one port of the multi-port memory; and executing program instructions stored in the multi-port memory concurrently on a first core of the multi-core processor so as to decode any one-dimensional bar code represented by the pixel data and on a second core of the multi-core processor so as to decode any two-dimensional bar code represented by the pixel data,

wherein the one-dimensional decoding and two-dimensional decoding run synchronously in parallel.

16. The method of claim **15**, wherein the executing step further includes executing program instructions stored in the multi-port memory on a third core of the multi-core processor so as to analyze the pixel data for image quality.

17. The method of claim **16**, wherein the executing step further includes executing program instructions stored in the multi-port memory on a fourth core of the multi-core processor so as to communicate with a network interface selected from the group consisting of an RS-232, RS-485, USB, Ethernet, Wi-Fi, IrDA and Zigbee interface.

18. A system of capturing an image and decoding any bar code in the image, comprising:

a multi-core processor having at least a first core and a second core;

a data storage means including at least one multi-port memory having at least a first port and a second port, the multi-port memory being in communication with at least one core of the multi-core processor;

at least one illumination assembly and at least one imaging assembly, the imaging assembly being configured to transmit image pixel data to the multi-port memory; and

wherein the data storage means comprises software including a one-dimensional decoder and a two-dimensional decoder that when executed causes each of the first and second cores of the multi-core processor to perform a respective method comprising:

decoding any one-dimensional bar code represented by the pixel data; and

decoding any two-dimensional bar code represented by the pixel data

wherein the one-dimensional decoding and two-dimensional decoding run synchronously in parallel.

19. The system of claim **18**, further including a network interface and wherein the multi-core processor further includes a third core and a fourth core and wherein the data storage means further comprises software including an image quality filter and at least one network communication routine that when executed causes the third and fourth cores of the multi-core processor to perform a respective method comprising:

analyze the pixel data for image quality; and

communicate with the network interface.

* * * * *

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(12) **United States Patent**
Wang

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(45) **Date of Patent: *Jul. 28, 2015**

(54) **LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD**

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G06K 7/10 (2006.01)
G06K 7/14 (2006.01)

(52) **U.S. Cl.**

CPC ***G06K 7/1404*** (2013.01); ***G06K 7/1093*** (2013.01); ***G06K 7/10722*** (2013.01)

(58) **Field of Classification Search**

USPC 345/501, 502, 505, 530, 554, 557; 235/462.01, 462.09, 462.1, 462.11; 718/105

See application file for complete search history.

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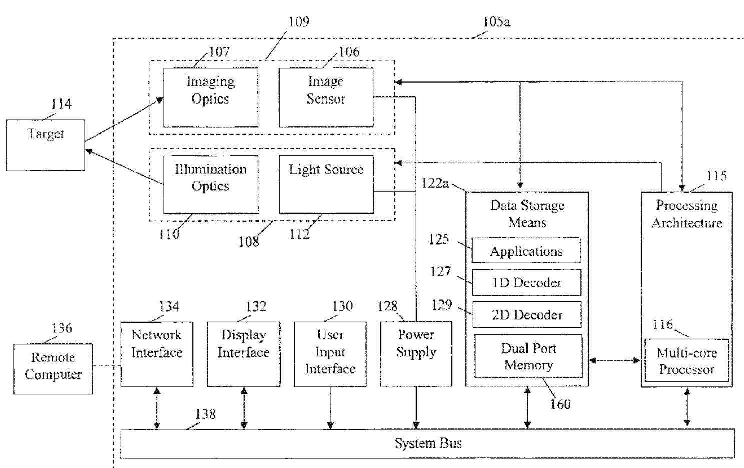
(57) **ABSTRACT**

A portable data terminal including a multi-core processor having at least a first core and a second core, at least one illumination assembly and at least one imaging assembly and data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder.

20 Claims, 5 Drawing Sheets



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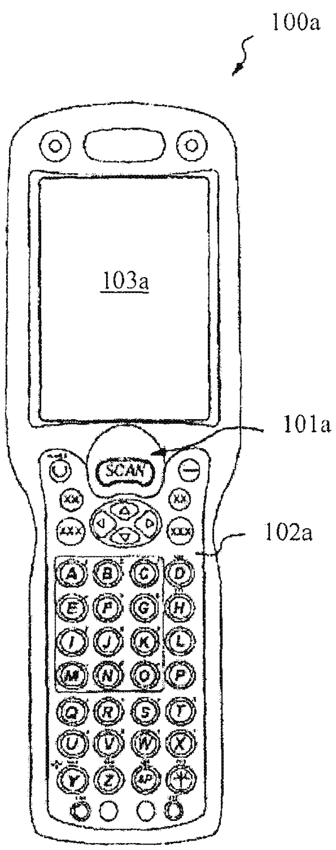

Fig. 1A

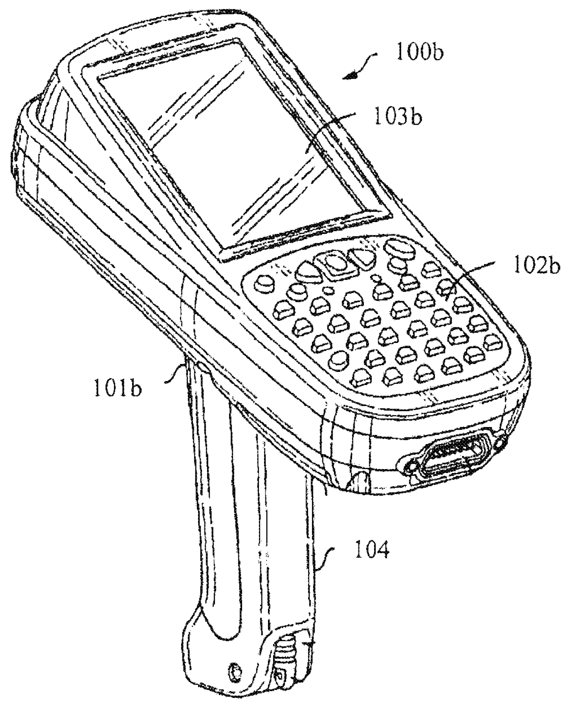

Fig. 1B

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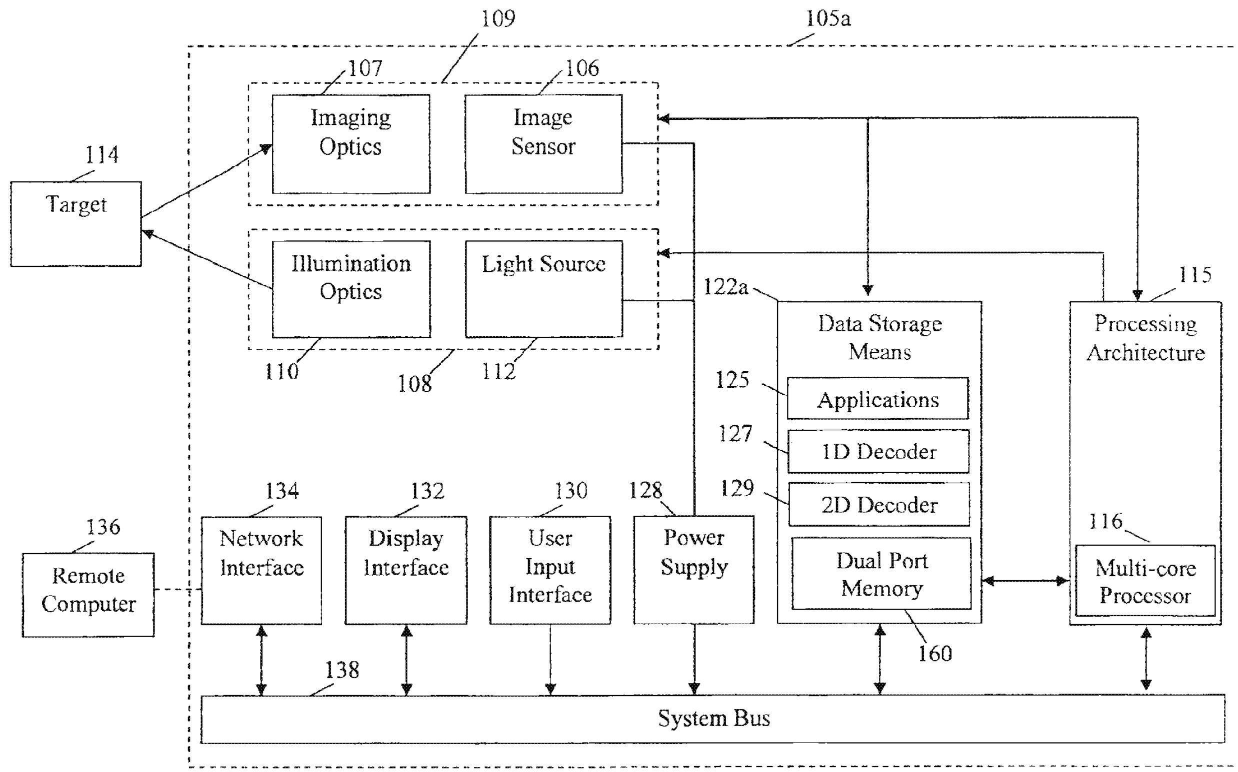

Fig. 2A

HONEYWELL-00228479

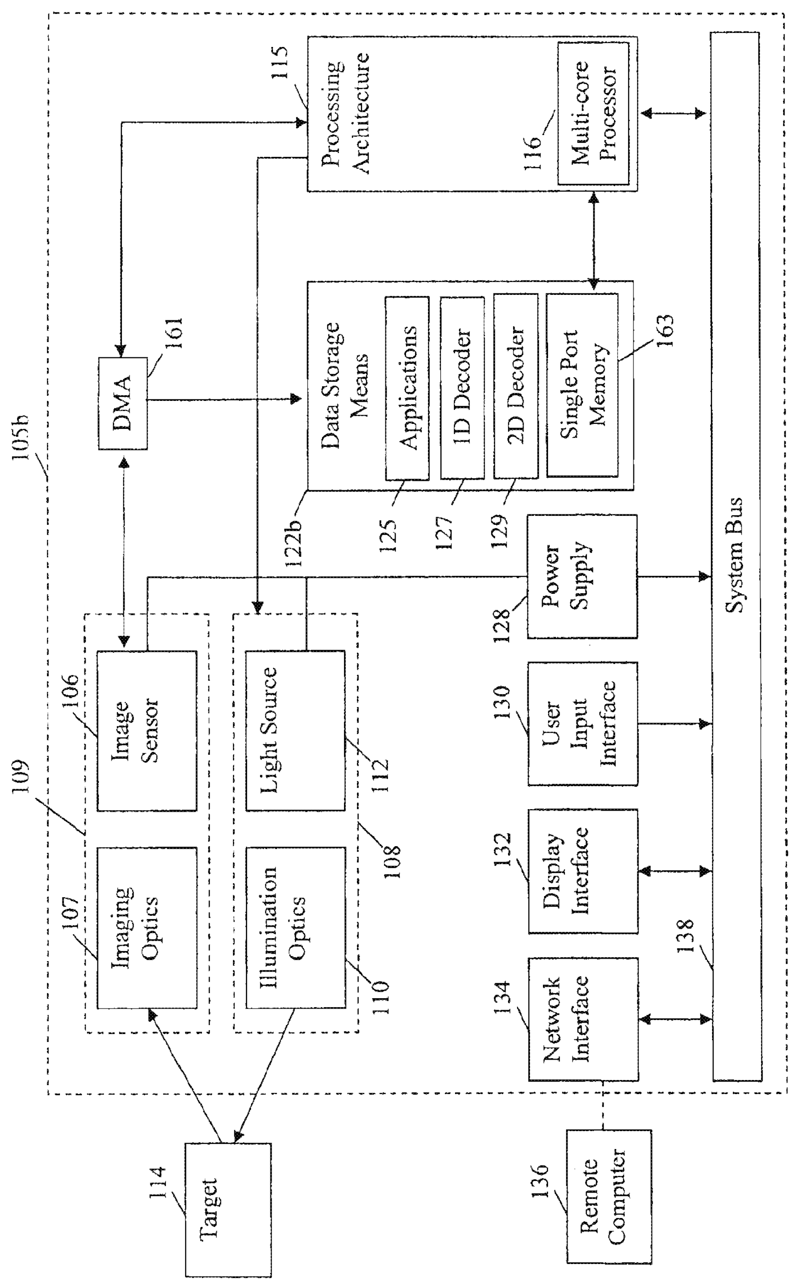
105b
115
Processing Architecture
116
Multi-core Processor
161
DMA
Data Storage Means
Applications
1D Decoder
2D Decoder
Single Port Memory
163
122b
125
127
129
109
106
Image Sensor
107
Imaging Optics
Light Source
112
108
Illumination Optics
110
128
Power Supply
130
User Input Interface
132
Display Interface
134
Network Interface
138
System Bus
114
Target
136
Remote Computer

Fig. 2B

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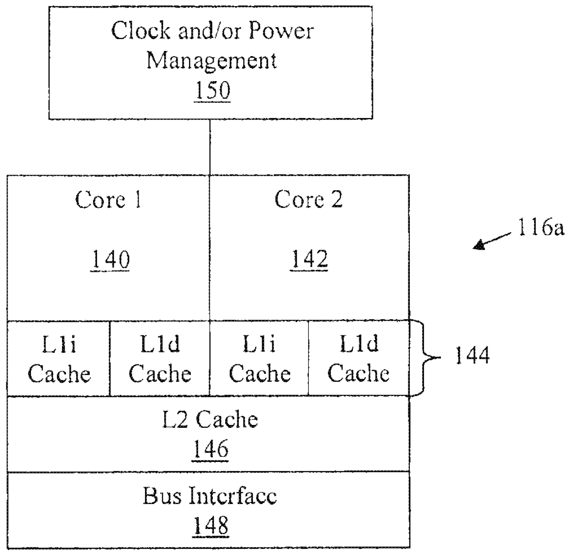

FIG. 3

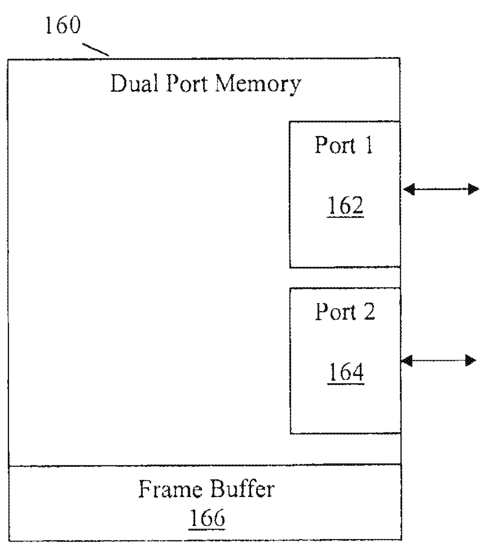

FIG. 4

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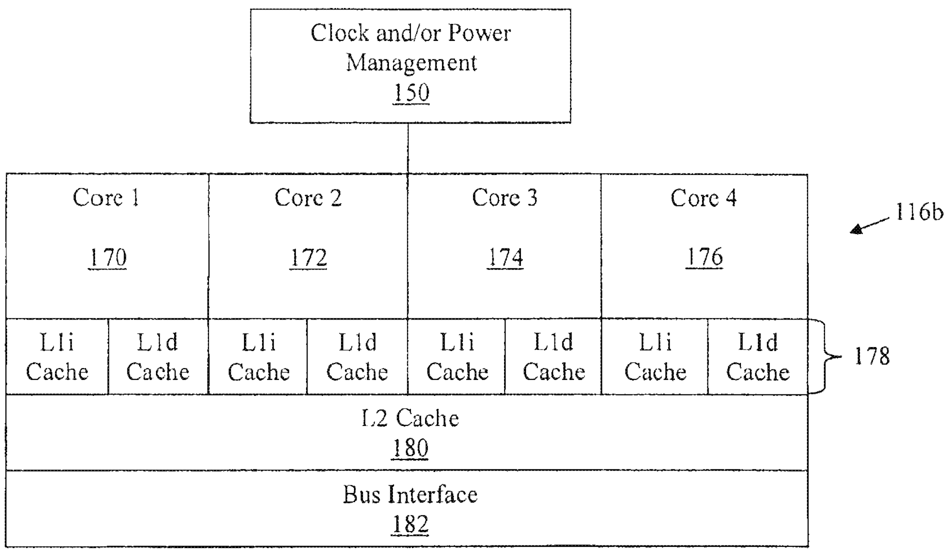
Clock and/or Power Management
150
Core 1
170
Core 2
172
Core 3
174
Core 4
176
116b
L1i Cache
L1d Cache
L1i Cache
L1d Cache
L1i Cache
L1d Cache
L1i Cache
L1d Cache
178
L2 Cache
180
Bus Interface
182

FIG. 5

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LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 12/571,911 filed Oct. 1, 2009 entitled, "Low Power Multi-Core Decoder System and Method." The above application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates to portable data terminals and more particularly, to portable data terminals configured to capture an image and decode any bar code contained in the image.

BACKGROUND INFORMATION

Portable data terminals (PDTs) such as laser indicia reading devices, optical indicia reading devices, barcode scanners and barcode readers, for example, typically read data represented by printed indicia such as symbols, symbology, and bar codes, for example. One type of symbol is an array of rectangular bars and spaces that are arranged in a specific way to represent elements of data in machine readable form. Optical indicia reading devices typically transmit light onto a symbol and receive light scattered and/or reflected back from a bar code symbol or indicia. The received light is interpreted by an image processor to extract the data represented by the symbol. Laser indicia reading devices typically utilize transmitted laser light. One-dimensional (1D) optical bar code readers are characterized by reading data that is encoded along a single axis, in the widths of bars and spaces, so that such symbols can be read from a single scan along that axis, provided that the symbol is imaged with a sufficiently high resolution.

In order to allow the encoding of larger amounts of data in a single bar code symbol, a number of one-dimensional (1D) stacked bar code symbologies have been developed which partition encoded data into multiple rows, each including a respective 1D bar code pattern, all or most all of which must be scanned and decoded, then linked together to form a complete message. Scanning still requires relatively higher resolution in one dimension only, but multiple linear scans are needed to read the whole symbol.

A class of bar code symbologies known as two-dimensional (2D) matrix symbologies have been developed which offer orientation-free scanning and greater data densities and capacities than 1D symbologies. 2D matrix codes encode data as dark or light data elements within a regular polygonal matrix, accompanied by graphical finder, orientation and reference structures.

Conventionally, a PDT includes a central processor which directly controls the operations of the various electrical components housed within the PDT. For example, the central processor controls detection of keypad entries, display features, wireless communication functions, trigger detection, and bar code read and decode functionality. More specifically, the central processor typically communicates with an illumination assembly configured to illuminate a target, such as a bar code, and an imaging assembly configured to receive an image of the target and generate an electric output signal indicative of the data optically encoded therein.

The output signal is generally representative of the pixel data transmitted by an image sensor of the imaging assembly. Because the pixel data may not be high enough quality for the processor to reliably decode the bar code in the image, PDTs generally successively capture images, or image frames, until a reliable decode is complete. Further, where the bar codes being decoded vary from 1D and 2D symbologies, the PDT generally sequentially executes decode algorithms for the multiple symbologies. This process can be time-intensive because the processor must wait for the pixel data to be stored in memory before it can access the data in order to execute a decode algorithm and then must further wait for a decode algorithm to complete before a second decode algorithm can execute. Further, in many settings such as warehouses, shopping centers, shipping centers, and numerous others, PDTs are used to decode bar codes in serial fashion such that a faster decode operation generally increases throughput.

Attempts have been made to increase decode speed particularly by multi-threading. Multi-threading, or hyper-threading, allows multiple threads to use a single processing unit by providing processor cycles to one thread when another thread incurs a latency such as a cache miss, for example, which would cause the processor to incur several cycles of idle time while off-chip memory is accessed. Using multi-threading, the central processor idle time is minimized but not substantially parallelized. Further, context switching between threads can significantly increase overhead, as the state of one process/thread is saved while another is loaded, further minimizing any efficiency gain.

Accordingly, there remains a need in the art for a PDT system architecture that will allow for faster, substantially parallel, bar code decoding operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is disclosed with reference to the accompanying drawings, wherein:

FIG. **1**A is a plan view of an exemplary PDT and FIG. **1**B is a side perspective view of an exemplary PDT.

FIG. **2**A is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **2**B is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **3** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

FIG. **4** is a block schematic diagram of an exemplary dual port memory module according to the present invention.

FIG. **5** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

It will be appreciated that for purposes of clarity and where deemed appropriate, reference numerals have been repeated in the figures to indicate corresponding features.

DETAILED DESCRIPTION

Referring to FIGS. **1**A and **1**B, two exemplary PDTs **100** for reading/scanning printed indicia are shown. The PDT housing can be shaped so as to fit comfortably into a human hand using a handle portion **104** and can include a finger actuatable scan/capture or trigger button **101** as well as a keypad **102** for inputting data and commands, power button, and antenna for facilitating communication with a local or remote host processor, for example. The PDT also includes a display **103**, such as an LCD or OLED display, for example, for displaying information to the user. If the display **103** is a touch screen, a stylus (not shown) may also be included to facilitate interaction with the touch screen. An aperture in the housing is included such that the illumination **108** and imaging optics **109** have substantially unobstructed access to the

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target **114**. The PDT can also include a power port for receiving a power supply as well as one or more communication ports for facilitating wired or wireless communication with a network interface **134**. Although the present invention is described with respect to a PDT, the invention can be utilized in any bar code scanner, mobile device, mobile computer, or personal data assistant, for example.

Referring to FIGS. **2**A and **2**B, there is shown a block schematic diagram of the basic structures that together comprise a PDT **105** according to the present invention. The PDT **105** includes an illumination assembly **108** for illuminating a target **114**, such as a bar code, and an imaging assembly **109** for receiving an image of the target **114** and generating an electric output signal indicative of the pixel data optically encoded therein. The illumination assembly **108** includes at least one light source **112** together with illumination optics **110**, such as one or more reflectors, for directing light from the light source in the direction of the target **114**. The light source **112** can include at least one LED configured to emit light in the near-infrared range and/or at least one LED configured to emit light in the visible range. The imaging assembly **102** includes a 2D image sensor **106**, such as a CCD, CMOS, NMOS, PMOS, CID, or CMD solid state imagine sensor, along with imaging optics **107** for receiving and focusing an image of the target **114** onto the image sensor **106**.

Still referring to FIGS. **2**A and **2**B, the PDT **105** further includes a processing architecture **115** which controls the operation of the PDT **105** by implementing program instructions it retrieves from the data storage means **122**. More specifically, the processing architecture **115** is configured to receive, output and process data, including image/pixel data, operate the imaging **109** and illumination **108** assemblies, and communicate with a system bus **138** among other operations. Further, the processing architecture **115** may be configured to control the illumination of the light source **112**, the timing of the image sensor **106**, analog-to-digital conversion, transmission and reception of data to and from a processor of a remote computer **136** external to the reader through a network interface **134**, such as an RS-232, RS-485, USB, Ethernet, Wi-Fi, Bluetooth.™., IrDA and Zigbee interface, control a user input interface to manage user interaction with a scan/trigger button **101** and/or keypad **102**, and control an output device **103**, such as an LCD or an OLED display, through the display interface **132**. The processing architecture **115** includes at least one multi-core processor **116** as described in detail below with respect to FIGS. **3** and **5** but optionally can include an additional processor(s) or microprocessor(s) such as VLSI or ASIC integrated circuit microprocessor(s). In one embodiment shown in FIG. **2**A the data storage means **122***a* includes at least one dual port memory module **160**, such as RAM for example, described in detail below with respect to FIG. **4** but optionally can include additional memory modules such as local, network-accessible, removable and/or non-removable memory, such as RAM, ROM, and/or flash. In another embodiment shown in FIG. **2**B, the data storage means **122***b* includes at least one single port memory module **163**, such as RAM for example, in communication with a direct memory access (DMA) controller **161** as described further below. The data storage means **122** is shown as including applications **125**, such as an operating system for example, a 1D decoder **127**, and a 2D decoder **129**. The decoders **127** and **129** include program instructions that, when executed by the multi-core processor **116**, retrieve image pixel data and decode any bar code contained in the image as is known in the art. Although the decoders **127** and **129** are shown as separate from the dual port memory **160** in FIG. **2**A, in another embodiment the decoder **127** and **129** program instructions are stored in the dual port memory **160**. The PDT **105** also includes one or more power supplies **128**, such as one or more batteries and/or circuitry for receiving an alternating current, and a user input interface **130** for receiving data from a user input device **102**, such as a keyboard, keypad, and/or touch screen. The PDT **105** structures shown in FIG. **2** are preferably supported on one or more printed circuit boards (not shown).

Referring to FIG. **3**, a multi-core processor **116** according to the present invention is shown as a dual-core processor **116***a* having a first core **140** and a second core **142**. The cores can also share one cache, or in a multilevel cache architecture, each utilize its own respective cache (e.g. L1) and share another cache (e.g. L2) or any combination thereof. In the embodiment shown in FIG. **3**, a first level of cache **144** is shown as having instruction and data caches for each core **140**, **142** and a second level of cache **146** is shown as being shared among both cores **140** and **142**. The cores **140** and **142** can be integrated on the same integrated circuit die or they can be integrated onto multiple dies in the same integrated circuit package as is known in the art. Further, the processor **116** can also include one or more independent or shared bus interfaces such as a shared bus interface **148** for communication with a system bus and/or the data storage means **122**. Each core **140** and **142** has its own processing unit and is capable of issuing instructions transmitted through the bus interface to a bus as well as simultaneously performing operations.

Referring to one embodiment shown in FIGS. **2**A and **4**, dual port memory **160** is shown as including a first port **162** and a second port **164**. At least a portion of the dual port memory, identified as frame buffer **166** in FIG. **4**, is configured to store image frame data as received from the image sensor. Dual port memory, such as the dual port memory described by U.S. Pat. No. 5,276,842 to Sugita, incorporated herein by reference, is preferably configured to be accessed by two cores simultaneously on the same clock. Contention issues are preferably handled by arbitration system or arbitration logic as is known in the art and as one exemplary implementation of an arbitration system is also described in the '842 patent. Dual port memory can also be implemented with a single port memory core as taught by Balasubramanian et al. in U.S. Pat. No. 7,349,285, incorporated herein by reference, whereby access requests are processed on both the high and low logic states of the memory clock cycle.

In an exemplary operation, the processing architecture **115** retrieves program instructions from data storage means **122***a*, over system bus **138**, which the architecture implements to control the illumination assembly **108** to focus light on a target **114** containing a bar code and imaging assembly **109** to receive the reflected light. The image sensor **106** then transmits output signals, representative of pixel data of the captured image, to the first port **162** of the dual port memory **164** where it is stored in a frame buffer **166**. Each of the first core **140** and the second core **142** can then access the frame buffer **166** and retrieve the pixel data. To allow for parallel decoding, the first core **140** can be configured to execute the program instructions of the 1D decoder and the second core **142** can be configured to execute the program instructions of the 2D decoder. Accordingly, whether the image contains a 1D or 2D bar code, decoding can occur at substantially the same time decreasing the time required for a successful decode. Further, image pixel/frame data can be stored in the dual port memory **160** on the same clock cycle as image pixel/frame data is being retrieved by the first core **140** and/or the second core **142**. PDT **105** can be configured to continuously image the target **114** and store the pixel data, or each frame, in the frame buffer and the cores **140** and **142** can continually process the

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image frame data, in parallel, until a successful decode event occurs. Upon successful decode, the decoded data is optionally transmitted to the data storage means **122** where it can be accessed, for example, by an application **125**.

In another embodiment, the first core is configured to execute 1D decoder **127** program instructions as well as image quality filter program instructions stored in data storage means **122**. When executed by the first core **140**, the image quality filter program instructions analyze, in real time, the pixel data/each frame retrieved by the core from the frame buffer for quality with respect to contrast, for example. The frame can then be assigned an image quality score which can be factored into a decode algorithm's decision with respect to selecting the highest image quality score frame available in the frame buffer. Further, the image quality filter program instructions can be configured to interrupt an existing decode **127** process which is decoding a frame/image with a low image quality score should a frame/image with a higher image quality score be captured.

In yet another embodiment, the first core **140** is configured to execute image quality filter program instructions, or any other program instructions related to image processing, for example, stored in data storage means **122** and the second core **142** is configured to execute 1D decoder **127** program instructions as well as 2D decoder program instructions **129**.

Referring to FIG. **5**, another embodiment is shown wherein the multi-core processor is a quad-core processor further including a third core and a fourth core as well as a first cache level **178**, a second shared cache level **180** and a bus interface **182**. A quad-core processor **116***b* generally refers to four processing units or cores **170**, **172**, **174** and **176** manufactured on the same integrated circuit. In this embodiment, the third core **174** can be configured to execute the program instructions of the image quality filter and the fourth core **176** can execute program instructions related to communication with the network interface **134**. Accordingly, the user does not have to wait to pull the trigger or press the scan button again until the first or second core has executed communication routines to transmit the decode results, for example through the network interface **134** to a remote computer **136**, because the fourth core **176** can handle communication with the network interface **134** in parallel with the first and/or second core causing the PDT **105** to capture a new image and begin a new process of decoding any bar code contained in the image.

Referring to FIG. **2**B, although the invention has thus far been described as including a dual port memory module, in another embodiment the data storage means **122***b* includes a single port memory **163** configured to store a frame buffer. In this embodiment, preferably a DMA controller **161** is included as being in communication with the imaging assembly **109**, the processing architecture **115** and the data storage means **122***b*. The DMA controller **161** can off-load the processor by transferring pixel data from the image sensor **106** directly to the single port memory **163** without involving the processing architecture **115** including the multi-core processor **116**. Accordingly, processor cycles that otherwise would be used to manage a frame buffer can instead be used to run decode **127**, **129** algorithms and/or otherwise as described above,

While the present invention substantially reduces the time required for a successful decode, it can also effectively manage the system clock and/or the power supplied to each core to reduce overall power consumption. Particularly in PDTs that are mostly powered by battery, power consumption is a concern because the greater the power dissipated, the faster the remaining battery life is reduced. Accordingly, and as shown in FIGS. **3** and **5**, a clock management module/logic **150** configured to dynamically vary the clock speed received by each respective core based on the workload/utilization of each core and/or a power management module/logic **150** configured to dynamically vary the voltage received by at least a portion of each core can be utilized to manage resources consumed by the multi-core processor **116***b*. One method of power management is described in U.S. patent application Ser. No. 11/238,489 to Borkar et al., incorporated herein by reference, as including voltage regulators to supply power to each core or a part of a core depending on a number of factors including activity, core temperature, transient current consumption, and reliability. Another method of power management has been described by Kim in U.S. patent application Ser. No. 11/424,080, incorporated herein by reference, which includes modulating the mode of the processor to single core or multi-core depending on a number of factors including whether the PDT is connected to AC or battery power, remaining battery level, available memory, and memory usage. One exemplary clock management module is disclosed by Naveh et al. in U.S. patent application Ser. No. 10/899,674, incorporated herein by reference, wherein the clock management module utilizes independent clock throttle settings for each core, independent clock throttle of various functional blocks of one or more core's internal architecture such as reorder buffers and reservation station tables, for example, and scaling the clock frequency of the bus that the multi-core processor uses to communicate with system components.

While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims.

What is claimed is:

1. A portable data terminal, comprising:

a multi-core processor having at least a first core and a second core, the multi-core processor receiving image data on a first clock cycle;

at least one illumination assembly and at least one imaging assembly; and

data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder, the decoders running in parallel on the first clock cycle, and

wherein the program instructions stored in the data storage means further includes an image quality filter.

2. The portable data terminal of claim **1** wherein the data storage means further includes including at least one multi-port memory module having at least a first port and a second port, the at least one multi-port memory module being configured to receive output signals from the imaging assembly and communicate with the multi-core processor.

3. The portable data terminal of claim **1** further including a power supply, at least one system bus, a network interface, a display interface, and a user input interface.

4. The portable data terminal of claim **1** further including at least one management module selected from the group consisting of a clock management module configured to dynamically vary the clock speed received by each respective core based on the workload of each core and a power management

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module configured to dynamically vary the voltage received by at least a portion of each core.

5. The portable data terminal of claim **1** wherein the first core of the multi-core processor executes the one-dimensional decoder and the second core executes the two-dimensional decoder.

6. The portable data terminal of claim **1** wherein the first core of the multi-core processor executes the image quality filter and the second core of the multi-core processor communicates with the network interface.

7. The portable data terminal of claim **1**, wherein the image quality filter is configured with filter program instructions that analyze pixel data retrieved by the multi-core processor and assign an image quality score to the pixel data.

8. The portable data terminal of claim **1**, wherein the multi-core processor comprises a frame buffer receiving the image data from the imaging assembly and the image quality filter assigns a score to each frame of data in the buffer.

9. The portable data terminal of claim **1**, wherein the image quality filter is processed in the first core.

10. The portable data terminal of claim **9**, wherein the second core processes the decoders.

11. A portable data terminal, comprising:

a multi-core processor having at least a first core and a second core;

at least one illumination assembly and at least one imaging assembly;

a dual port memory receiving output signals from the imaging assembly on a first clock cycle and the multi-core processor retrieving image data from the dual port memory on the first clock cycle;

data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder; and

wherein the first core of the multi-core processor executes the one-dimensional decoder and the second core executes the two-dimensional decoder, and

wherein the one-dimensional decoder and two-dimensional decoder run in parallel and on the first clock cycle.

12. The portable data terminal of claim **11**, comprising a first level of cache and a second level of cache, the first level including an instruction cache and a data cache for each core and the second level being shared among all the cores.

13. The portable data terminal of claim **11**, wherein the multi-core processor comprises a third core and a fourth core, wherein the program instructions stored in the data storage means comprises an image quality filter and wherein the third core of the multi-core processor executes the image quality filter and the fourth core of the multi-core processor communicates with the network interface.

14. The portable data terminal of claim **11**, comprising a direct memory access controller in communication with the imaging assembly, multi-core processor and data storage means and wherein the data storage means comprises at least one single port memory module.

15. A portable data terminal, comprising:

a multi-core processor having at least a first core and a second core;

at least one illumination assembly and at least one imaging assembly;

a dual port memory receiving output signals from the imaging assembly on a first clock cycle and the multi-core processor retrieving image data from the dual port memory on the first clock cycle;

data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder; and

wherein the one-dimensional decoder and two-dimensional decoder run in parallel and on the first clock cycle.

16. The portable data terminal of claim **15**, comprising a power supply, at least one system bus, a network interface, a display interface, a system bus, and a user input interface.

17. The portable data terminal of claim **15**, wherein the imaging assembly comprises imaging optics and an image sensor and the illumination assembly comprises illumination optics and at least one light source.

18. The portable data terminal of claim **15**, comprising at least one management module selected from the group consisting of a clock management module configured to dynamically vary the clock speed received by each respective core based on the workload of each core and a power management module configured to dynamically vary the voltage received by at least a portion of each core.

19. The portable data terminal of claim **15**, wherein a first port of the memory is configured to receive at least one output signal from the imaging assembly, the output signals representing pixel data transmitted by the image sensor, and a second port of the memory is configured to communicate with the multi-core processor.

20. The portable data terminal of claim **15**, wherein the multi-core processor comprises a third core and a fourth core, wherein the program instructions stored in the data storage means comprises an image quality filter and wherein the third core of the multi-core processor executes the image quality filter and the fourth core of the multi-core processor communicates with the network interface.

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(12) **United States Patent**
Wang

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(54) **LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD**

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This patent is subject to a terminal disclaimer.

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G06K 7/10 (2006.01)
G06K 19/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G06K 7/1447*** (2013.01); ***G06K 7/1093*** (2013.01); ***G06K 7/10722*** (2013.01); ***G06K 7/10881*** (2013.01); ***G06K 7/1404*** (2013.01); ***G06K 7/1408*** (2013.01); ***G06K 7/1413*** (2013.01); ***G06K 7/1417*** (2013.01); ***G06K 19/06028*** (2013.01); ***G06K 19/06037*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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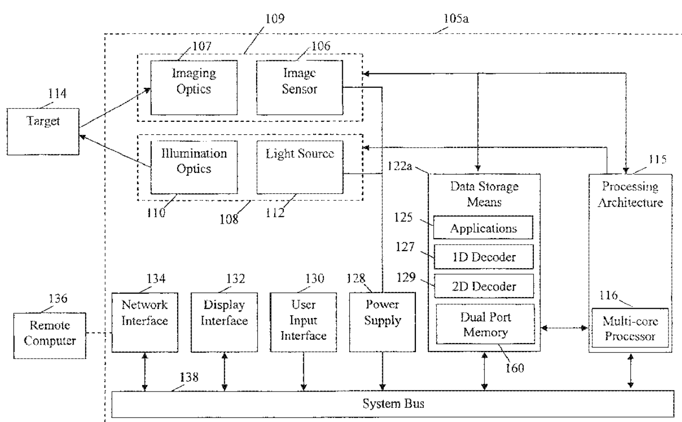
(57) **ABSTRACT**

A portable data terminal including a multi-core processor having at least a first core and a second core, at least one illumination assembly and at least one imaging assembly and data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder.

20 Claims, 5 Drawing Sheets



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2004/0262399	A1	12/2004	Longacre et al.
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2006/0175413	A1	8/2006	Longacre, Jr. et al.
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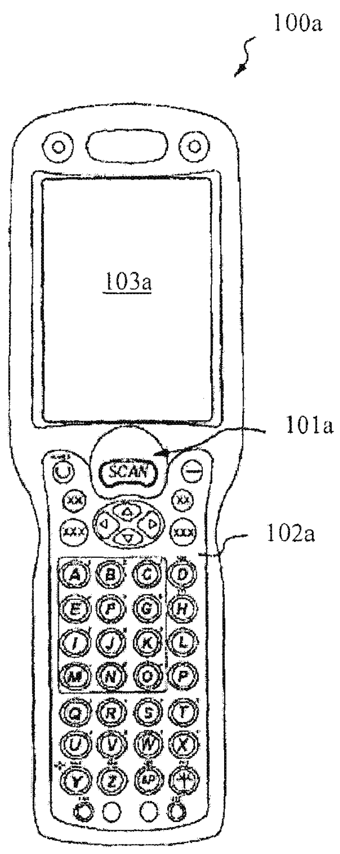

Fig. 1A

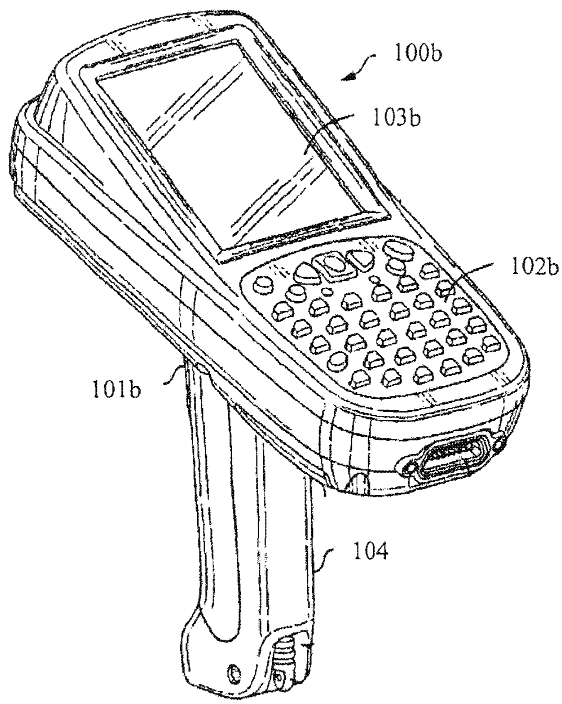

Fig. 1B

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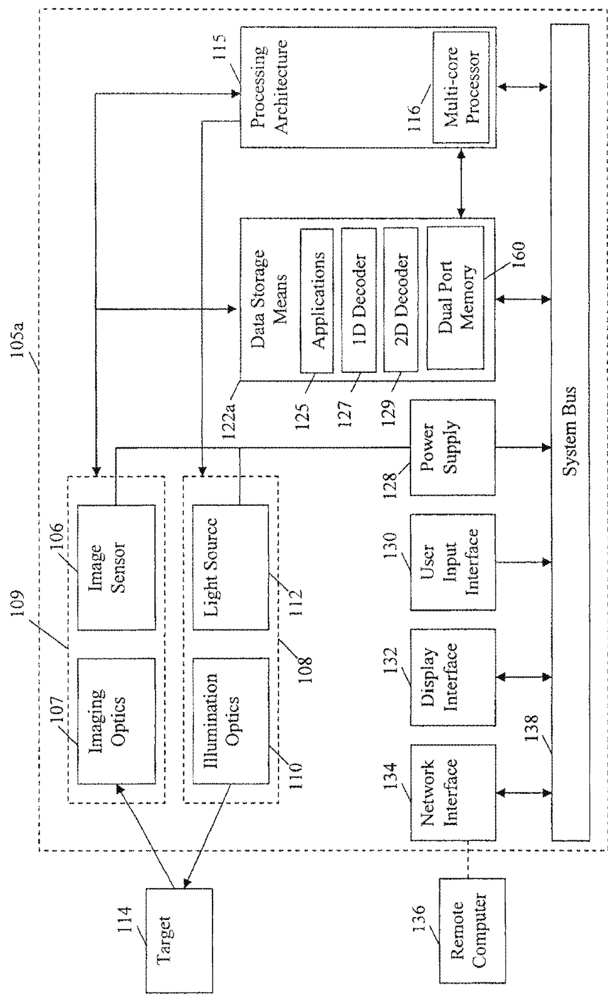
105a
115
Processing Architecture
116
Multi-core Processor
Data Storage Means
Applications
1D Decoder
2D Decoder
Dual Port Memory
160
122a
125
127
129
109
106
Image Sensor
107
Imaging Optics
Light Source
112
Illumination Optics
108
110
128
Power Supply
130
User Input Interface
132
Display Interface
134
Network Interface
138
System Bus
114
Target
136
Remote Computer

Fig. 2A

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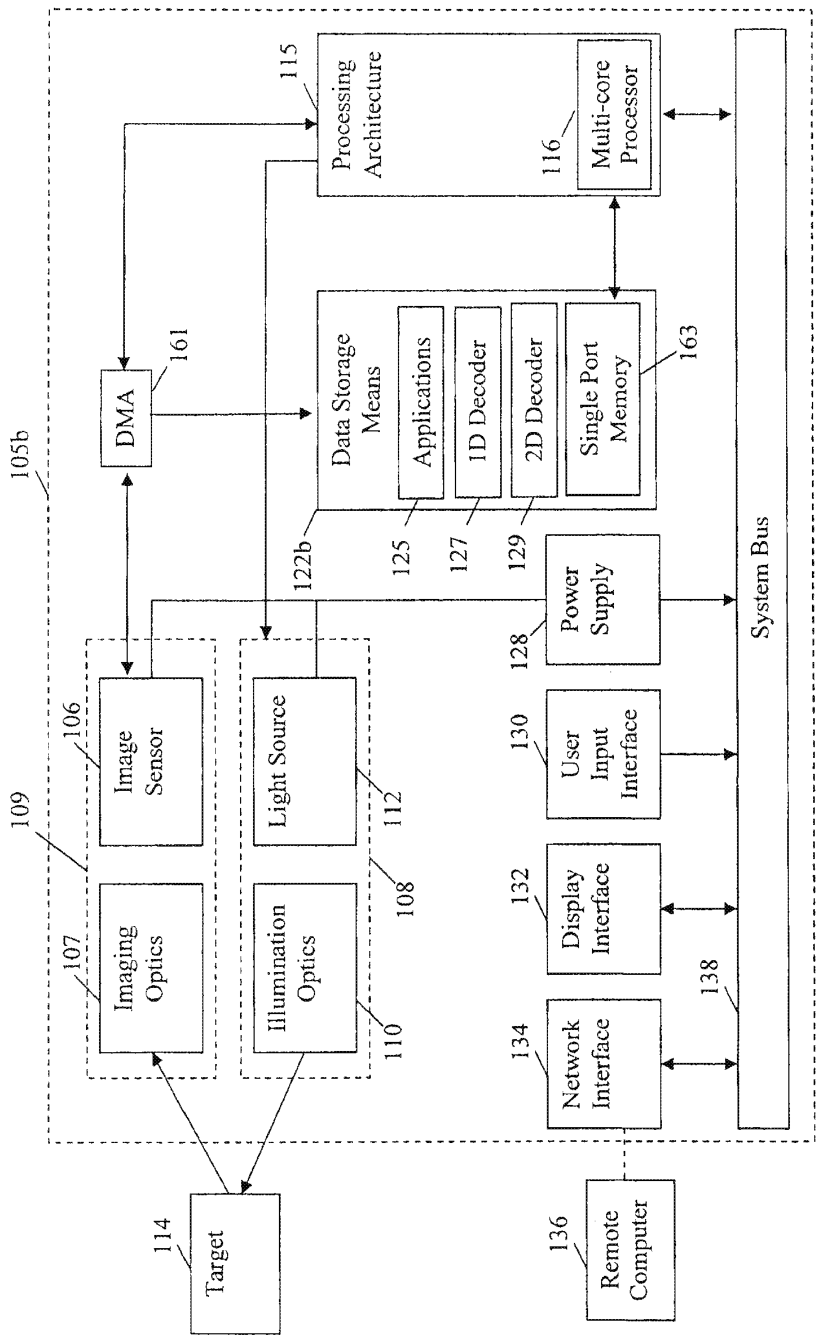
105b
Processing Architecture
115
116
Multi-core Processor
DMA
161
Data Storage Means
Applications
1D Decoder
2D Decoder
Single Port Memory
163
122b
125
127
129
Power Supply
128
System Bus
109
106
Image Sensor
Light Source
112
User Input Interface
130
107
Imaging Optics
Illumination Optics
108
110
Display Interface
132
138
Network Interface
134
Target
114
Remote Computer
136

Fig. 2B

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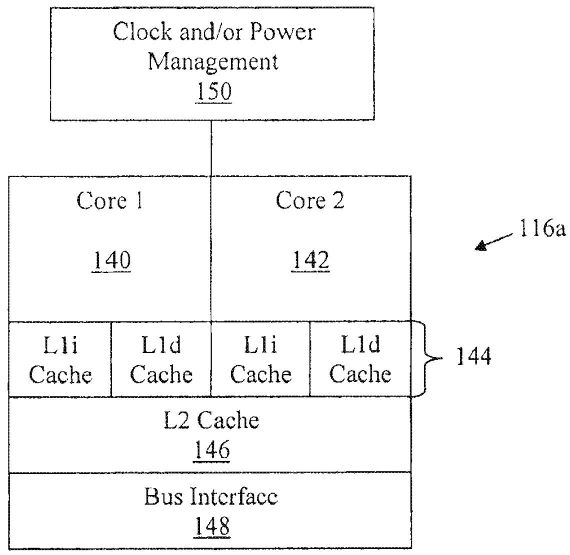

FIG. 3

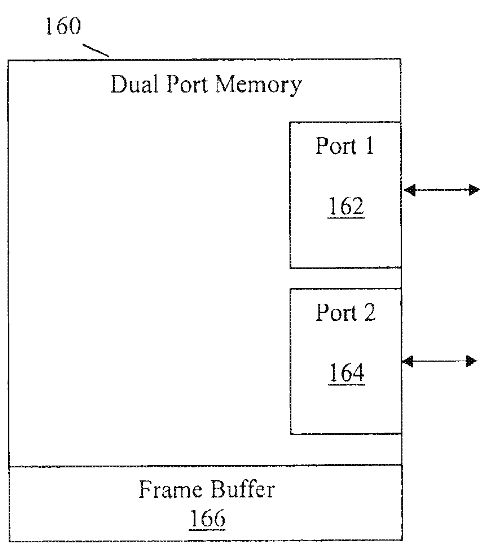

FIG. 4

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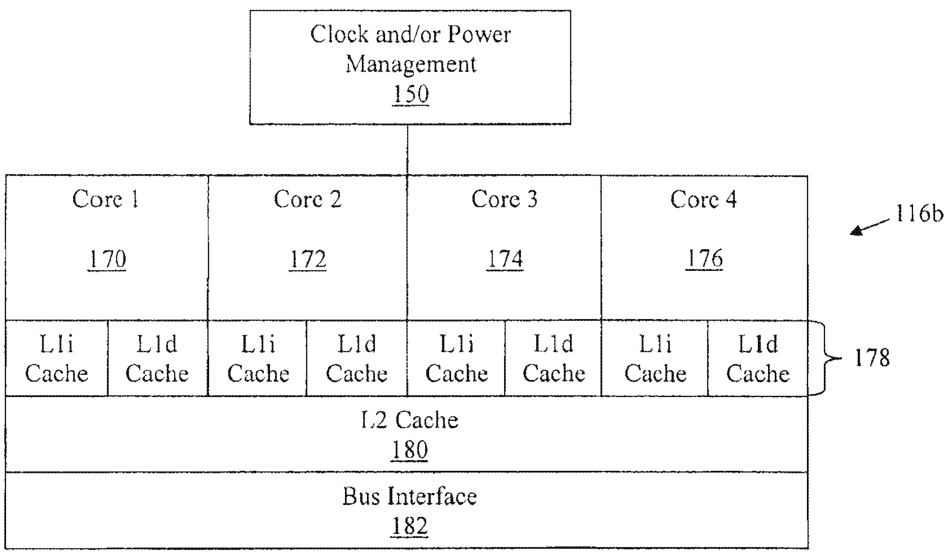
Clock and/or Power Management
150
Core 1
170
Core 2
172
Core 3
174
Core 4
176
116b
L1i Cache
L1d Cache
L1i Cache
L1d Cache
L1i Cache
L1d Cache
L1i Cache
L1d Cache
178
L2 Cache
180
Bus Interface
182

FIG. 5

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LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of U.S. patent application Ser. No. 14/808,464 for a Low Power Multi-Core Decoder System and Method filed Jul. 24, 2015 (and published Nov. 19, 2015 as U.S. Patent Publication No. 2015/0332078), now U.S. Pat. No. 9,384,378, which claims the benefit of U.S. patent application Ser. No. 13/932,634 for a Low Power Multi-Core Decoder System and Method filed Jul. 1, 2013 (and published Jan. 9, 2014 as U.S. Patent Publication No. 2014/0008439), now U.S. Pat. No. 9,092, 686, which claims the benefit of U.S. patent application Ser. No. 12/571,911 for a Low Power Multi-Core Decoder System and Method filed Oct. 1, 2009 (and published Apr. 7, 2011 as U.S. Patent Publication No. 2011/0080414), now U.S. Pat. No. 8,587,595. Each of the foregoing patent applications, patent publications, and patents is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present invention relates to portable data terminals and more particularly, to portable data terminals configured to capture an image and decode any bar code contained in the image.

BACKGROUND INFORMATION

Portable data terminals (PDTs) such as laser indicia reading devices, optical indicia reading devices, barcode scanners and barcode readers, for example, typically read data represented by printed indicia such as symbols, symbology, and bar codes, for example. One type of symbol is an array of rectangular bars and spaces that are arranged in a specific way to represent elements of data in machine readable form. Optical indicia reading devices typically transmit light onto a symbol and receive light scattered and/or reflected back from a bar code symbol or indicia. The received light is interpreted by an image processor to extract the data represented by the symbol. Laser indicia reading devices typically utilize transmitted laser light. One-dimensional (1D) optical bar code readers are characterized by reading data that is encoded along a single axis, in the widths of bars and spaces, so that such symbols can be read from a single scan along that axis, provided that the symbol is imaged with a sufficiently high resolution.

In order to allow the encoding of larger amounts of data in a single bar code symbol, a number of one-dimensional (1D) stacked bar code symbologies have been developed which partition encoded data into multiple rows, each including a respective 1D bar code pattern, all or most all of which must be scanned and decoded, then linked together to form a complete message. Scanning still requires relatively higher resolution in one dimension only, but multiple linear scans are needed to read the whole symbol.

A class of bar code symbologies known as two-dimensional (2D) matrix symbologies have been developed which offer orientation-free scanning and greater data densities and capacities than 1D symbologies. 2D matrix codes encode data as dark or light data elements within a regular polygonal matrix, accompanied by graphical finder, orientation and reference structures.

Conventionally, a PDT includes a central processor which directly controls the operations of the various electrical components housed within the PDT. For example, the central processor controls detection of keypad entries, display features, wireless communication functions, trigger detection, and bar code read and decode functionality. More specifically, the central processor typically communicates with an illumination assembly configured to illuminate a target, such as a bar code, and an imaging assembly configured to receive an image of the target and generate an electric output signal indicative of the data optically encoded therein.

The output signal is generally representative of the pixel data transmitted by an image sensor of the imaging assembly. Because the pixel data may not be high enough quality for the processor to reliably decode the bar code in the image, PDTs generally successively capture images, or image frames, until a reliable decode is complete. Further, where the bar codes being decoded vary from 1D and 2D symbologies, the PDT generally sequentially executes decode algorithms for the multiple symbologies. This process can be time-intensive because the processor must wait for the pixel data to be stored in memory before it can access the data in order to execute a decode algorithm and then must further wait for a decode algorithm to complete before a second decode algorithm can execute. Further, in many settings such as warehouses, shopping centers, shipping centers, and numerous others, PDTs are used to decode bar codes in serial fashion such that a faster decode operation generally increases throughput.

Attempts have been made to increase decode speed particularly by multi-threading. Multi-threading, or hyper-threading, allows multiple threads to use a single processing unit by providing processor cycles to one thread when another thread incurs a latency such as a cache miss, for example, which would cause the processor to incur several cycles of idle time while off-chip memory is accessed. Using multi-threading, the central processor idle time is minimized but not substantially parallelized. Further, context switching between threads can significantly increase overhead, as the state of one process/thread is saved while another is loaded, further minimizing any efficiency gain.

Accordingly, there remains a need in the art for a PDT system architecture that will allow for faster, substantially parallel, bar code decoding operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is disclosed with reference to the accompanying drawings, wherein:

FIG. **1**A is a plan view of an exemplary PDT and FIG. **1**B is a side perspective view of an exemplary PDT.

FIG. **2**A is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **2**B is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **3** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

FIG. **4** is a block schematic diagram of an exemplary dual port memory module according to the present invention.

FIG. **5** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

It will be appreciated that for purposes of clarity and where deemed appropriate, reference numerals have been repeated in the figures to indicate corresponding features.

DETAILED DESCRIPTION

Referring to FIGS. **1**A and **1**B, two exemplary PDTs **100** for reading/scanning printed indicia are shown. The PDT

housing can be shaped so as to fit comfortably into a human hand using a handle portion **104** and can include a finger actuatable scan/capture or trigger button **101** as well as a keypad **102** for inputting data and commands, power button, and antenna for facilitating communication with a local or remote host processor, for example. The PDT also includes a display **103**, such as an LCD or OLED display, for example, for displaying information to the user. If the display **103** is a touch screen, a stylus (not shown) may also be included to facilitate interaction with the touch screen. An aperture in the housing is included such that the illumination **108** and imaging optics **109** have substantially unobstructed access to the target **114**. The PDT can also include a power port for receiving a power supply as well as one or more communication ports for facilitating wired or wireless communication with a network interface **134**. Although the present invention is described with respect to a PDT, the invention can be utilized in any bar code scanner, mobile device, mobile computer, or personal data assistant, for example.

Referring to FIGS. **2**A and **2**B, there is shown a block schematic diagram of the basic structures that together comprise a PDT **105** according to the present invention. The PDT **105** includes an illumination assembly **108** for illuminating a target **114**, such as a bar code, and an imaging assembly **109** for receiving an image of the target **114** and generating an electric output signal indicative of the pixel data optically encoded therein. The illumination assembly **108** includes at least one light source **112** together with illumination optics **110**, such as one or more reflectors, for directing light from the light source in the direction of the target **114**. The light source **112** can include at least one LED configured to emit light in the near-infrared range and/or at least one LED configured to emit light in the visible range. The imaging assembly **102** includes a 2D image sensor **106**, such as a CCD, CMOS, NMOS, PMOS, CID, or CMD solid state imagine sensor, along with imaging optics **107** for receiving and focusing an image of the target **114** onto the image sensor **106**.

Still referring to FIGS. **2**A and **2**B, the PDT **105** further includes a processing architecture **115** which controls the operation of the PDT **105** by implementing program instructions it retrieves from the data storage means **122**. More specifically, the processing architecture **115** is configured to receive, output and process data, including image/pixel data, operate the imaging **109** and illumination **108** assemblies, and communicate with a system bus **138** among other operations. Further, the processing architecture **115** may be configured to control the illumination of the light source **112**, the timing of the image sensor **106**, analog-to-digital conversion, transmission and reception of data to and from a processor of a remote computer **136** external to the reader through a network interface **134**, such as an RS-232, RS-485, USB, Ethernet, Wi-Fi, Bluetooth™, IrDA and Zigbee interface, control a user input interface to manage user interaction with a scan/trigger button **101** and/or keypad **102**, and control an output device **103**, such as an LCD or an OLED display, through the display interface **132**. The processing architecture **115** includes at least one multi-core processor **116** as described in detail below with respect to FIGS. **3** and **5** but optionally can include an additional processor(s) or microprocessor(s) such as VLSI or ASIC integrated circuit microprocessor(s). In one embodiment shown in FIG. **2**A the data storage means **122***a* includes at least one dual port memory module **160**, such as RAM for example, described in detail below with respect to FIG. **4** but optionally can include additional memory modules such as local, network-accessible, removable and/or non-removable memory, such as RAM, ROM, and/or flash. In another embodiment shown in FIG. **2**B, the data storage means **122***b* includes at least one single port memory module **163**, such as RAM for example, in communication with a direct memory access (DMA) controller **161** as described further below. The data storage means **122** is shown as including applications **125**, such as an operating system for example, a 1D decoder **127**, and a 2D decoder **129**. The decoders **127** and **129** include program instructions that, when executed by the multi-core processor **116**, retrieve image pixel data and decode any bar code contained in the image as is known in the art. Although the decoders **127** and **129** are shown as separate from the dual port memory **160** in FIG. **2**A, in another embodiment the decoder **127** and **129** program instructions are stored in the dual port memory **160**. The PDT **105** also includes one or more power supplies **128**, such as one or more batteries and/or circuitry for receiving an alternating current, and a user input interface **130** for receiving data from a user input device **102**, such as a keyboard, keypad, and/or touch screen. The PDT **105** structures shown in FIG. **2** are preferably supported on one or more printed circuit boards (not shown).

Referring to FIG. **3**, a multi-core processor **116** according to the present invention is shown as a dual-core processor **116***a* having a first core **140** and a second core **142**. The cores can also share one cache, or in a multilevel cache architecture, each utilize its own respective cache (e.g. L1) and share another cache (e.g. L2) or any combination thereof. In the embodiment shown in FIG. **3**, a first level of cache **144** is shown as having instruction and data caches for each core **140**, **142** and a second level of cache **146** is shown as being shared among both cores **140** and **142**. The cores **140** and **142** can be integrated on the same integrated circuit die or they can be integrated onto multiple dies in the same integrated circuit package as is known in the art. Further, the processor **116** can also include one or more independent or shared bus interfaces such as a shared bus interface **148** for communication with a system bus and/or the data storage means **122**. Each core **140** and **142** has its own processing unit and is capable of issuing instructions transmitted through the bus interface to a bus as well as simultaneously performing operations.

Referring to one embodiment shown in FIGS. **2**A and **4**, dual port memory **160** is shown as including a first port **162** and a second port **164**. At least a portion of the dual port memory, identified as frame buffer **166** in FIG. **4**, is configured to store image frame data as received from the image sensor. Dual port memory, such as the dual port memory described by U.S. Pat. No. 5,276,842 to Sugita, incorporated herein by reference, is preferably configured to be accessed by two cores simultaneously on the same clock. Contention issues are preferably handled by arbitration system or arbitration logic as is known in the art and as one exemplary implementation of an arbitration system is also described in the '842 patent. Dual port memory can also be implemented with a single port memory core as taught by Balasubramanian et al. in U.S. Pat. No. 7,349,285, incorporated herein by reference, whereby access requests are processed on both the high and low logic states of the memory clock cycle.

In an exemplary operation, the processing architecture **115** retrieves program instructions from data storage means **122***a*, over system bus **138**, which the architecture implements to control the illumination assembly **108** to focus light on a target **114** containing a bar code and imaging assembly **109** to receive the reflected light. The image sensor **106** then transmits output signals, representative of pixel data of the

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captured image, to the first port **162** of the dual port memory **164** where it is stored in a frame buffer **166**. Each of the first core **140** and the second core **142** can then access the frame buffer **166** and retrieve the pixel data. To allow for parallel decoding, the first core **140** can be configured to execute the program instructions of the 1D decoder and the second core **142** can be configured to execute the program instructions of the 2D decoder. Accordingly, whether the image contains a 1D or 2D bar code, decoding can occur at substantially the same time decreasing the time required for a successful decode. Further, image pixel/frame data can be stored in the dual port memory **160** on the same clock cycle as image pixel/frame data is being retrieved by the first core **140** and/or the second core **142**. PDT **105** can be configured to continuously image the target **114** and store the pixel data, or each frame, in the frame buffer and the cores **140** and **142** can continually process the image frame data, in parallel, until a successful decode event occurs. Upon successful decode, the decoded data is optionally transmitted to the data storage means **122** where it can be accessed, for example, by an application **125**.

In another embodiment, the first core is configured to execute 1D decoder **127** program instructions as well as image quality filter program instructions stored in data storage means **122**. When executed by the first core **140**, the image quality filter program instructions analyze, in real time, the pixel data/each frame retrieved by the core from the frame buffer for quality with respect to contrast, for example. The frame can then be assigned an image quality score which can be factored into a decode algorithm's decision with respect to selecting the highest image quality score frame available in the frame buffer. Further, the image quality filter program instructions can be configured to interrupt an existing decode **127** process which is decoding a frame/image with a low image quality score should a frame/image with a higher image quality score be captured.

In yet another embodiment, the first core **140** is configured to execute image quality filter program instructions, or any other program instructions related to image processing, for example, stored in data storage means **122** and the second core **142** is configured to execute 1D decoder **127** program instructions as well as 2D decoder program instructions **129**.

Referring to FIG. **5**, another embodiment is shown wherein the multi-core processor is a quad-core processor further including a third core and a fourth core as well as a first cache level **178**, a second shared cache level **180** and a bus interface **182**. A quad-core processor **116***b* generally refers to four processing units or cores **170**, **172**, **174** and **176** manufactured on the same integrated circuit. In this embodiment, the third core **174** can be configured to execute the program instructions of the image quality filter and the fourth core **176** can execute program instructions related to communication with the network interface **134**. Accordingly, the user does not have to wait to pull the trigger or press the scan button again until the first or second core has executed communication routines to transmit the decode results, for example through the network interface **134** to a remote computer **136**, because the fourth core **176** can handle communication with the network interface **134** in parallel with the first and/or second core causing the PDT **105** to capture a new image and begin a new process of decoding any bar code contained in the image.

Referring to FIG. 2B, although the invention has thus far been described as including a dual port memory module, in another embodiment the data storage means **122***b* includes a single port memory **163** configured to store a frame buffer. In this embodiment, preferably a DMA controller **161** is included as being in communication with the imaging assembly **109**, the processing architecture **115** and the data storage means **122***b*. The DMA controller **161** can off-load the processor by transferring pixel data from the image sensor **106** directly to the single port memory **163** without involving the processing architecture **115** including the multi-core processor **116**. Accordingly, processor cycles that otherwise would be used to manage a frame buffer can instead be used to run decode **127**, **129** algorithms and/or otherwise as described above,

While the present invention substantially reduces the time required for a successful decode, it can also effectively manage the system clock and/or the power supplied to each core to reduce overall power consumption. Particularly in PDTs that are mostly powered by battery, power consumption is a concern because the greater the power dissipated, the faster the remaining battery life is reduced. Accordingly, and as shown in FIGS. **3** and **5**, a clock management module/logic **150** configured to dynamically vary the clock speed received by each respective core based on the workload/utilization of each core and/or a power management module/logic **150** configured to dynamically vary the voltage received by at least a portion of each core can be utilized to manage resources consumed by the multi-core processor **116***b*. One method of power management is described in U.S. patent application Ser. No. 11/238,489 to Borkar et al., incorporated herein by reference, as including voltage regulators to supply power to each core or a part of a core depending on a number of factors including activity, core temperature, transient current consumption, and reliability. Another method of power management has been described by Kim in U.S. patent application Ser. No. 11/424,080, incorporated herein by reference, which includes modulating the mode of the processor to single core or multi-core depending on a number of factors including whether the PDT is connected to AC or battery power, remaining battery level, available memory, and memory usage. One exemplary clock management module is disclosed by Naveh et al. in U.S. patent application Ser. No. 10/899,674, incorporated herein by reference, wherein the clock management module utilizes independent clock throttle settings for each core, independent clock throttle of various functional blocks of one or more core's internal architecture such as reorder buffers and reservation station tables, for example, and scaling the clock frequency of the bus that the multi-core processor uses to communicate with system components.

While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims.

I claim:

1. A method, comprising:

capturing an image of a target with an image sensor of a portable data terminal, the portable data terminal comprising the image sensor, a processor, memory, and a network interface;

synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the captured image and decoding, with the processor, any two-dimensional symbol in the captured image; and

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transmitting, with the network interface, data regarding the decoding of any one-dimensional symbol and/or the decoding of any two-dimensional symbol.

2. The method of claim **1**, comprising, with the processor, storing the captured image in the memory.

3. The method of claim **1**, comprising, with the processor, analyzing the captured image for image quality.

4. The method of claim **1**, comprising:

transferring image data to the memory; and

storing the transferred image data in the memory;

wherein synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the captured image and decoding, with the processor, any two-dimensional symbol in the captured image comprises synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the stored image data and decoding, with the processor, any two-dimensional symbol in the stored image data.

5. The method of claim **1**, wherein the processor is a multi-core processor.

6. The method of claim **1**, wherein:

the processor is a multi-core processor comprising a first core and a second core; and

synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the captured image and decoding, with the processor, any two-dimensional symbol in the captured image comprises synchronously and in parallel, decoding, with the first core, any one-dimensional symbol in the captured image and decoding, with the second core, any two-dimensional symbol in the captured image.

7. A method, comprising:

capturing an image of a target with an image sensor of a portable data terminal, the portable data terminal comprising the image sensor, a processor, and memory; and

synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the captured image and decoding, with the processor, any two-dimensional symbol in the captured image.

8. The method of claim **7**, comprising, with the processor, storing the captured image in the memory.

9. The method of claim **7**, comprising, with the processor, analyzing the captured image for image quality.

10. The method of claim **7**, comprising communicating with a network interface.

11. The method of claim **7**, comprising:

transferring image data to the memory; and

storing the transferred image data in the memory;

wherein synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the captured image and decoding, with the processor, any two-dimensional symbol in the captured image comprises synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the stored image data and decoding, with the processor, any two-dimensional symbol in the stored image data.

12. The method of claim **7**, wherein the processor is a multi-core processor.

13. The method of claim **7**, wherein:

the processor is a multi-core processor comprising a first core and a second core; and

synchronously and in parallel, decoding, with the processor, any one-dimensional symbol in the captured image and decoding, with the processor, any two-dimensional symbol in the captured image comprises synchronously and in parallel, decoding, with the first core, any one-dimensional symbol in the captured image and decoding, with the second core, any two-dimensional symbol in the captured image.

14. A method, comprising:

capturing an image of a target with a portable data terminal having a processor; and

synchronously and in parallel, decoding, with the processor, any one-dimensional bar code in the captured image and decoding, with the processor, any two-dimensional bar code in the captured image.

15. The method of claim **14**, comprising, with the processor, storing the captured image in a memory of the portable data terminal.

16. The method of claim **14**, comprising, with the processor, analyzing the captured image for image quality.

17. The method of claim **14**, comprising communicating with a network interface.

18. The method of claim **14**, comprising:

transferring image data to a memory of the portable data terminal; and

storing the transferred image data in the memory;

wherein synchronously and in parallel, decoding, with the processor, any one-dimensional bar code in the captured image and decoding, with the processor, any two-dimensional bar code in the captured image comprises synchronously and in parallel, decoding, with the processor, any one-dimensional bar code in the stored image data and decoding, with the processor, any two-dimensional bar code in the stored image data.

19. The method of claim **14**, wherein the processor is a multi-core processor.

20. The method of claim **14**, wherein:

the processor is a multi-core processor comprising a first core and a second core; and

synchronously and in parallel, decoding, with the processor, any one-dimensional bar code in the captured image and decoding, with the processor, any two-dimensional bar code in the captured image comprises synchronously and in parallel, decoding, with the first core, any one-dimensional bar code in the captured image and decoding, with the second core, any two-dimensional bar code in the captured image.

* * * * *

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(12) **United States Patent**
Wang

(10) **Patent No.: US 9,384,378 B2**
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(54) **LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD**

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CPC ***G06K 7/1417*** (2013.01); ***G06K 7/1093*** (2013.01); ***G06K 7/10722*** (2013.01); ***G06K 7/10881*** (2013.01); ***G06K 7/1404*** (2013.01); ***G06K 7/1408*** (2013.01); ***G06K 7/1413*** (2013.01)

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None
See application file for complete search history.

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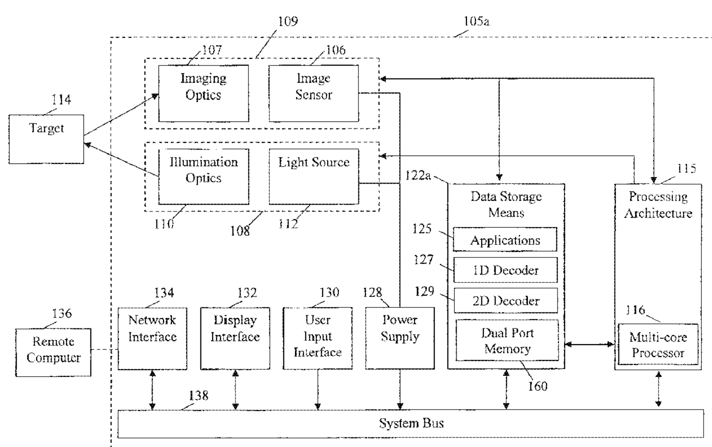
(57) **ABSTRACT**

A portable data terminal including a multi-core processor having at least a first core and a second core, at least one illumination assembly and at least one imaging assembly and data storage means configured to store a plurality of program instructions, the program instructions including at least one one-dimensional decoder and at least one two-dimensional decoder.

20 Claims, 5 Drawing Sheets



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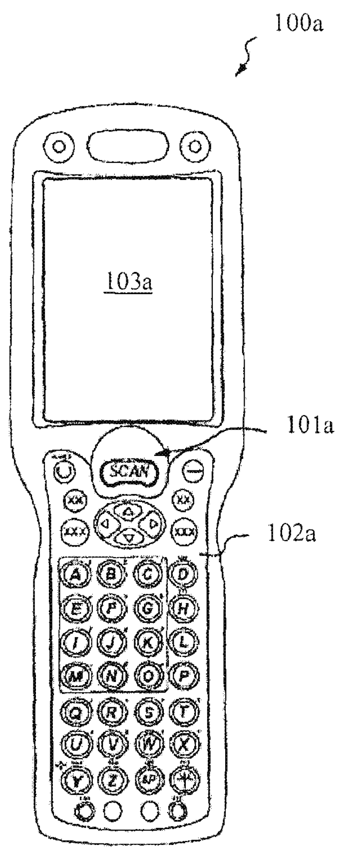

Fig. 1A

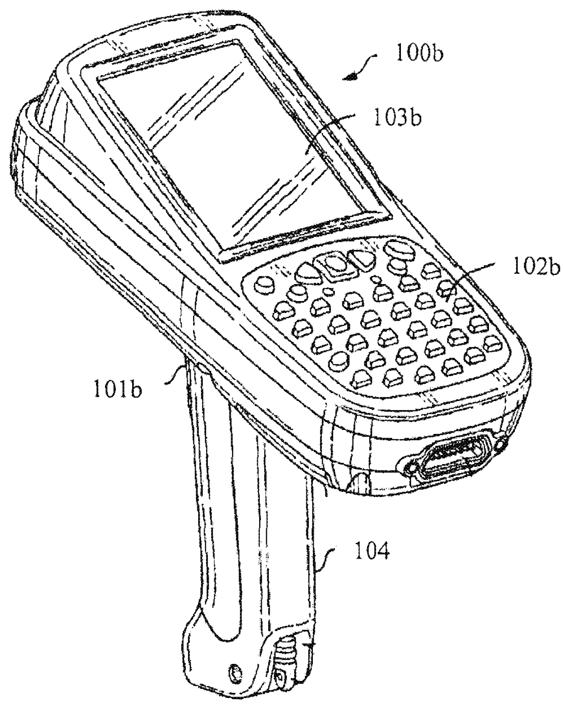

Fig. 1B

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HONEYWELL-00234832

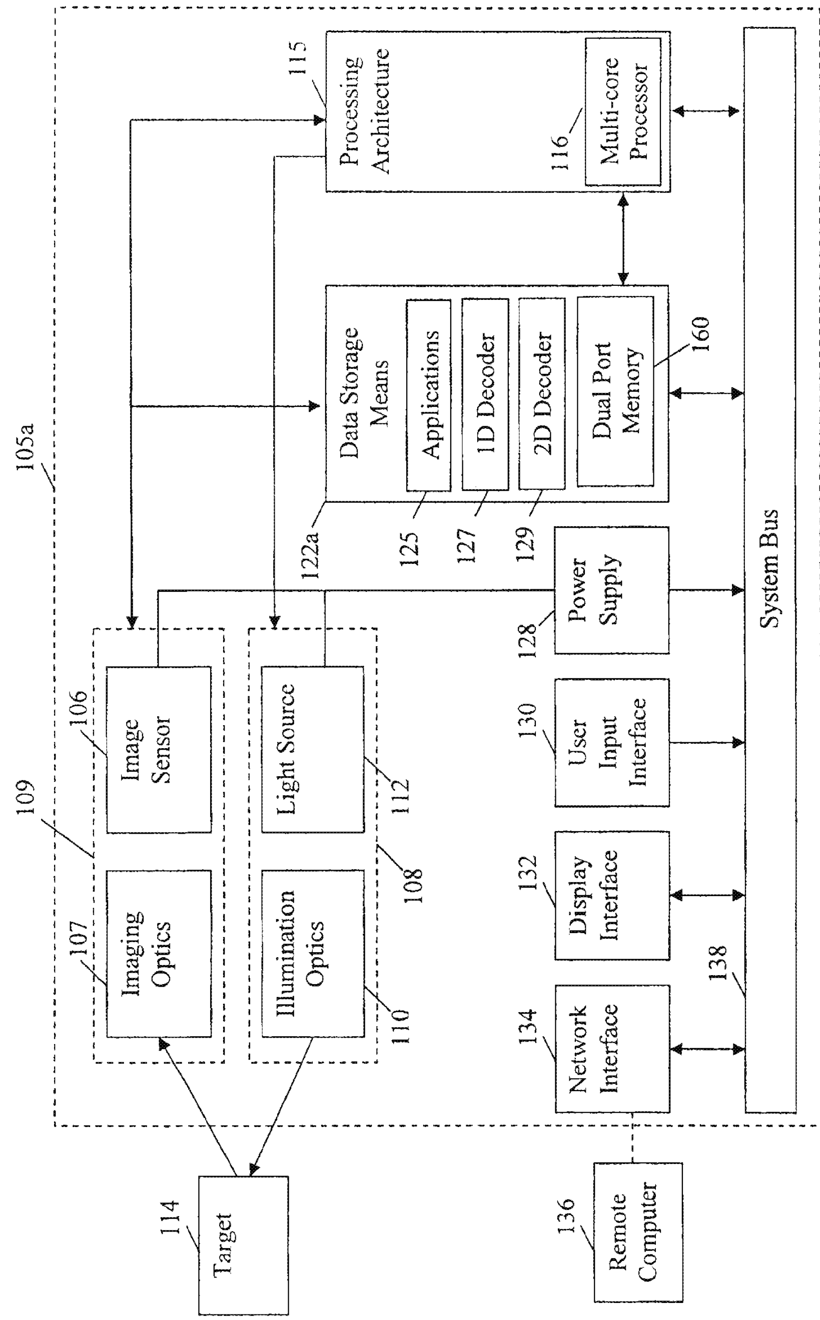

Fig. 2A

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HONEYWELL-00234833

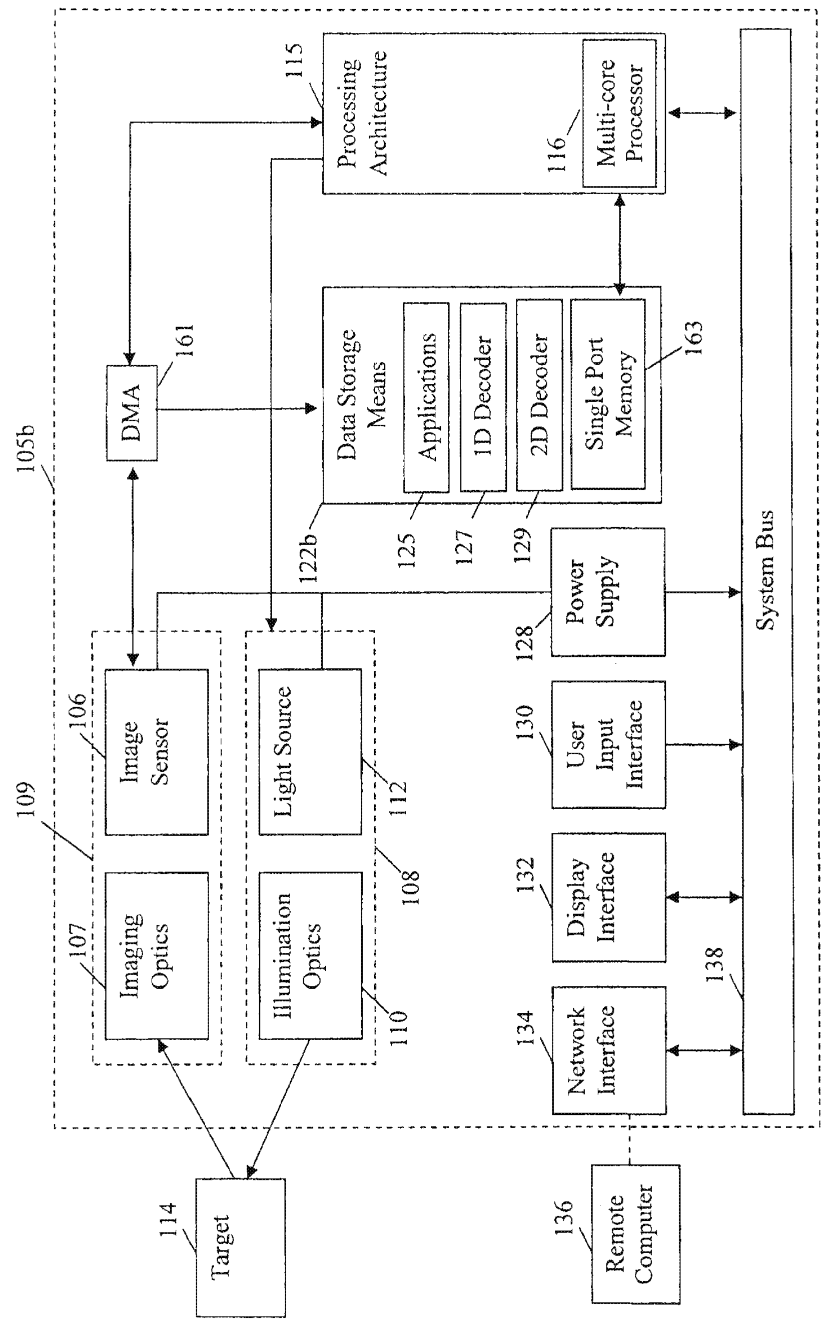

Fig. 2B

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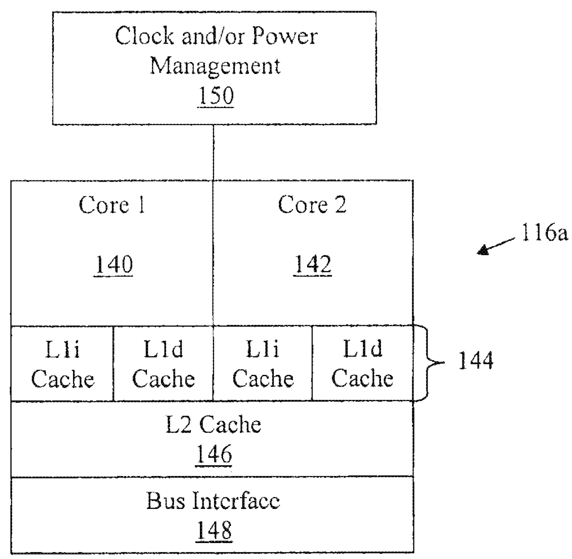

FIG. 3

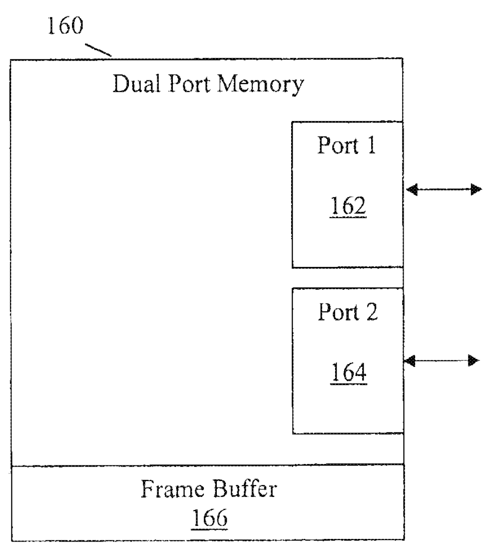

FIG. 4

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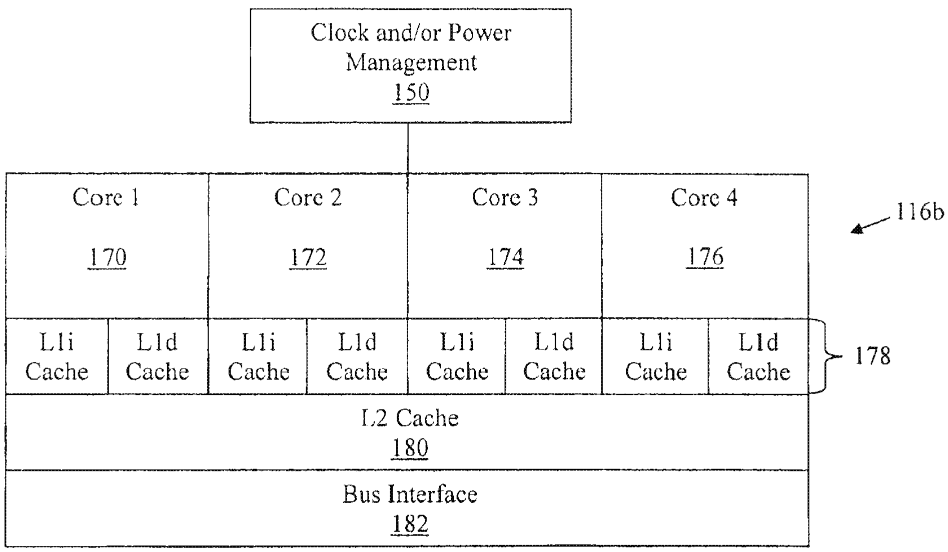

Clock and/or Power Management
150
Core 1
170
Core 2
172
Core 3
174
Core 4
176
116b
L1i Cache
L1d Cache
L1i Cache
L1d Cache
L1i Cache
L1d Cache
L1i Cache
L1d Cache
178
L2 Cache
180
Bus Interface
182

FIG. 5

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LOW POWER MULTI-CORE DECODER SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of and claims priority to U.S. patent application Ser. No. 13/932,634, filed Jul. 1, 2013, entitled, "Low Power Multi-Core Decoder System and Method," which issued on Jul. 28, 2015, as U.S. Pat. No. 9,092,686. This application is also a continuation of and claims priority to U.S. patent application Ser. No. 12/571,911 filed Oct. 1, 2009 entitled, "Low Power Multi-Core Decoder System and Method," which issued on Nov. 19, 2013, as U.S. Pat. No. 8,587,595. The above application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates to portable data terminals and more particularly, to portable data terminals configured to capture an image and decode any bar code contained in the image.

BACKGROUND INFORMATION

Portable data terminals (PDTs) such as laser indicia reading devices, optical indicia reading devices, barcode scanners and barcode readers, for example, typically read data represented by printed indicia such as symbols, symbology, and bar codes, for example. One type of symbol is an array of rectangular bars and spaces that are arranged in a specific way to represent elements of data in machine readable form. Optical indicia reading devices typically transmit light onto a symbol and receive light scattered and/or reflected back from a bar code symbol or indicia. The received light is interpreted by an image processor to extract the data represented by the symbol. Laser indicia reading devices typically utilize transmitted laser light. One-dimensional (1D) optical bar code readers are characterized by reading data that is encoded along a single axis, in the widths of bars and spaces, so that such symbols can be read from a single scan along that axis, provided that the symbol is imaged with a sufficiently high resolution.

In order to allow the encoding of larger amounts of data in a single bar code symbol, a number of one-dimensional (1D) stacked bar code symbologies have been developed which partition encoded data into multiple rows, each including a respective 1D bar code pattern, all or most all of which must be scanned and decoded, then linked together to form a complete message. Scanning still requires relatively higher resolution in one dimension only, but multiple linear scans are needed to read the whole symbol.

A class of bar code symbologies known as two-dimensional (2D) matrix symbologies have been developed which offer orientation-free scanning and greater data densities and capacities than 1D symbologies. 2D matrix codes encode data as dark or light data elements within a regular polygonal matrix, accompanied by graphical finder, orientation and reference structures.

Conventionally, a PDT includes a central processor which directly controls the operations of the various electrical components housed within the PDT. For example, the central processor controls detection of keypad entries, display features, wireless communication functions, trigger detection, and bar code read and decode functionality. More specifically, the central processor typically communicates with an illumination assembly configured to illuminate a target, such as a bar code, and an imaging assembly configured to receive an image of the target and generate an electric output signal indicative of the data optically encoded therein.

The output signal is generally representative of the pixel data transmitted by an image sensor of the imaging assembly. Because the pixel data may not be high enough quality for the processor to reliably decode the bar code in the image, PDTs generally successively capture images, or image frames, until a reliable decode is complete. Further, where the bar codes being decoded vary from 1D and 2D symbologies, the PDT generally sequentially executes decode algorithms for the multiple symbologies. This process can be time-intensive because the processor must wait for the pixel data to be stored in memory before it can access the data in order to execute a decode algorithm and then must further wait for a decode algorithm to complete before a second decode algorithm can execute. Further, in many settings such as warehouses, shopping centers, shipping centers, and numerous others, PDTs are used to decode bar codes in serial fashion such that a faster decode operation generally increases throughput.

Attempts have been made to increase decode speed particularly by multi-threading. Multi-threading, or hyper-threading, allows multiple threads to use a single processing unit by providing processor cycles to one thread when another thread incurs a latency such as a cache miss, for example, which would cause the processor to incur several cycles of idle time while off-chip memory is accessed. Using multi-threading, the central processor idle time is minimized but not substantially parallelized. Further, context switching between threads can significantly increase overhead, as the state of one process/thread is saved while another is loaded, further minimizing any efficiency gain.

Accordingly, there remains a need in the art for a PDT system architecture that will allow for faster, substantially parallel, bar code decoding operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is disclosed with reference to the accompanying drawings, wherein:

FIG. **1**A is a plan view of an exemplary PDT and FIG. **1**B is a side perspective view of an exemplary PDT.

FIG. **2**A is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **2**B is a block schematic diagram of an exemplary PDT according to the present invention.

FIG. **3** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

FIG. **4** is a block schematic diagram of an exemplary dual port memory module according to the present invention.

FIG. **5** is a block schematic diagram of an exemplary multi-core processor according to the present invention.

It will be appreciated that for purposes of clarity and where deemed appropriate, reference numerals have been repeated in the figures to indicate corresponding features.

DETAILED DESCRIPTION

Referring to FIGS. **1**A and **1**B, two exemplary PDTs **100** for reading/scanning printed indicia are shown. The PDT housing can be shaped so as to fit comfortably into a human hand using a handle portion **104** and can include a finger actuatable scan/capture or trigger button **101** as well as a keypad **102** for inputting data and commands, power button, and antenna for facilitating communication with a local or remote host processor, for example. The PDT also includes a

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display **103**, such as an LCD or OLED display, for example, for displaying information to the user. If the display **103** is a touch screen, a stylus (not shown) may also be included to facilitate interaction with the touch screen. An aperture in the housing is included such that the illumination **108** and imaging optics **109** have substantially unobstructed access to the target **114**. The PDT can also include a power port for receiving a power supply as well as one or more communication ports for facilitating wired or wireless communication with a network interface **134**. Although the present invention is described with respect to a PDT, the invention can be utilized in any bar code scanner, mobile device, mobile computer, or personal data assistant, for example.

Referring to FIGS. **2**A and **2**B, there is shown a block schematic diagram of the basic structures that together comprise a PDT **105** according to the present invention. The PDT **105** includes an illumination assembly **108** for illuminating a target **114**, such as a bar code, and an imaging assembly **109** for receiving an image of the target **114** and generating an electric output signal indicative of the pixel data optically encoded therein. The illumination assembly **108** includes at least one light source **112** together with illumination optics **110**, such as one or more reflectors, for directing light from the light source in the direction of the target **114**. The light source **112** can include at least one LED configured to emit light in the near-infrared range and/or at least one LED configured to emit light in the visible range. The imaging assembly **102** includes a 2D image sensor **106**, such as a CCD, CMOS, NMOS, PMOS, CID, or CMD solid state imagine sensor, along with imaging optics **107** for receiving and focusing an image of the target **114** onto the image sensor **106**.

Still referring to FIGS. **2**A and **2**B, the PDT **105** further includes a processing architecture **115** which controls the operation of the PDT **105** by implementing program instructions it retrieves from the data storage means **122**. More specifically, the processing architecture **115** is configured to receive, output and process data, including image/pixel data, operate the imaging **109** and illumination **108** assemblies, and communicate with a system bus **138** among other operations. Further, the processing architecture **115** may be configured to control the illumination of the light source **112**, the timing of the image sensor **106**, analog-to-digital conversion, transmission and reception of data to and from a processor of a remote computer **136** external to the reader through a network interface **134**, such as an RS-232, RS-485, USB, Ethernet, Wi-Fi, Bluetooth™, IrDA and Zigbee interface, control a user input interface to manage user interaction with a scan/trigger button **101** and/or keypad **102**, and control an output device **103**, such as an LCD or an OLED display, through the display interface **132**. The processing architecture **115** includes at least one multi-core processor **116** as described in detail below with respect to FIGS. **3** and **5** but optionally can include an additional processor(s) or microprocessor(s) such as VLSI or ASIC integrated circuit microprocessor(s). In one embodiment shown in FIG. **2**A the data storage means **122*a*** includes at least one dual port memory module **160**, such as RAM for example, described in detail below with respect to FIG. **4** but optionally can include additional memory modules such as local, network-accessible, removable and/or non-removable memory, such as RAM, ROM, and/or flash. In another embodiment shown in FIG. **2**B, the data storage means **122*b*** includes at least one single port memory module **163**, such as RAM for example, in communication with a direct memory access (DMA) controller **161** as described further below. The data storage means **122** is shown as including applications **125**, such as an operating system for example, a 1D decoder **127**, and a 2D decoder **129**. The decoders **127** and **129** include program instructions that, when executed by the multi-core processor **116**, retrieve image pixel data and decode any bar code contained in the image as is known in the art. Although the decoders **127** and **129** are shown as separate from the dual port memory **160** in FIG. **2**A, in another embodiment the decoder **127** and **129** program instructions are stored in the dual port memory **160**. The PDT **105** also includes one or more power supplies **128**, such as one or more batteries and/or circuitry for receiving an alternating current, and a user input interface **130** for receiving data from a user input device **102**, such as a keyboard, keypad, and/or touch screen. The PDT **105** structures shown in FIG. **2** are preferably supported on one or more printed circuit boards (not shown).

Referring to FIG. **3**, a multi-core processor **116** according to the present invention is shown as a dual-core processor **116*a*** having a first core **140** and a second core **142**. The cores can also share one cache, or in a multilevel cache architecture, each utilize its own respective cache (e.g. L1) and share another cache (e.g. L2) or any combination thereof. In the embodiment shown in FIG. **3**, a first level of cache **144** is shown as having instruction and data caches for each core **140**, **142** and a second level of cache **146** is shown as being shared among both cores **140** and **142**. The cores **140** and **142** can be integrated on the same integrated circuit die or they can be integrated onto multiple dies in the same integrated circuit package as is known in the art. Further, the processor **116** can also include one or more independent or shared bus interfaces such as a shared bus interface **148** for communication with a system bus and/or the data storage means **122**. Each core **140** and **142** has its own processing unit and is capable of issuing instructions transmitted through the bus interface to a bus as well as simultaneously performing operations.

Referring to one embodiment shown in FIGS. **2**A and **4**, dual port memory **160** is shown as including a first port **162** and a second port **164**. At least a portion of the dual port memory, identified as frame buffer **166** in FIG. **4**, is configured to store image frame data as received from the image sensor. Dual port memory, such as the dual port memory described by U.S. Pat. No. 5,276,842 to Sugita, incorporated herein by reference, is preferably configured to be accessed by two cores simultaneously on the same clock. Contention issues are preferably handled by arbitration system or arbitration logic as is known in the art and as one exemplary implementation of an arbitration system is also described in the ’842 patent. Dual port memory can also be implemented with a single port memory core as taught by Balasubramanian et al. in U.S. Pat. No. 7,349,285, incorporated herein by reference, whereby access requests are processed on both the high and low logic states of the memory clock cycle.

In an exemplary operation, the processing architecture **115** retrieves program instructions from data storage means **122*a***, over system bus **138**, which the architecture implements to control the illumination assembly **108** to focus light on a target **114** containing a bar code and imaging assembly **109** to receive the reflected light. The image sensor **106** then transmits output signals, representative of pixel data of the captured image, to the first port **162** of the dual port memory **164** where it is stored in a frame buffer **166**. Each of the first core **140** and the second core **142** can then access the frame buffer **166** and retrieve the pixel data. To allow for parallel decoding, the first core **140** can be configured to execute the program instructions of the 1D decoder and the second core **142** can be configured to execute the program instructions of the 2D decoder. Accordingly, whether the image contains a 1D or 2D bar code, decoding can occur at substantially the same time decreasing the time required for a successful decode. Further,

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image pixel/frame data can be stored in the dual port memory **160** on the same clock cycle as image pixel/frame data is being retrieved by the first core **140** and/or the second core **142**. PDT **105** can be configured to continuously image the target **114** and store the pixel data, or each frame, in the frame buffer and the cores **140** and **142** can continually process the image frame data, in parallel, until a successful decode event occurs. Upon successful decode, the decoded data is optionally transmitted to the data storage means **122** where it can be accessed, for example, by an application **125**.

In another embodiment, the first core is configured to execute 1D decoder **127** program instructions as well as image quality filter program instructions stored in data storage means **122**. When executed by the first core **140**, the image quality filter program instructions analyze, in real time, the pixel data/each frame retrieved by the core from the frame buffer for quality with respect to contrast, for example. The frame can then be assigned an image quality score which can be factored into a decode algorithm's decision with respect to selecting the highest image quality score frame available in the frame buffer. Further, the image quality filter program instructions can be configured to interrupt an existing decode **127** process which is decoding a frame/image with a low image quality score should a frame/image with a higher image quality score be captured.

In yet another embodiment, the first core **140** is configured to execute image quality filter program instructions, or any other program instructions related to image processing, for example, stored in data storage means **122** and the second core **142** is configured to execute 1D decoder **127** program instructions as well as 2D decoder program instructions **129**.

Referring to FIG. **5**, another embodiment is shown wherein the multi-core processor is a quad-core processor further including a third core and a fourth core as well as a first cache level **178**, a second shared cache level **180** and a bus interface **182**. A quad-core processor **116***b* generally refers to four processing units or cores **170**, **172**, **174** and **176** manufactured on the same integrated circuit. In this embodiment, the third core **174** can be configured to execute the program instructions of the image quality filter and the fourth core **176** can execute program instructions related to communication with the network interface **134**. Accordingly, the user does not have to wait to pull the trigger or press the scan button again until the first or second core has executed communication routines to transmit the decode results, for example through the network interface **134** to a remote computer **136**, because the fourth core **176** can handle communication with the network interface **134** in parallel with the first and/or second core causing the PDT **105** to capture a new image and begin a new process of decoding any bar code contained in the image.

Referring to FIG. **2**B, although the invention has thus far been described as including a dual port memory module, in another embodiment the data storage means **122***b* includes a single port memory **163** configured to store a frame buffer. In this embodiment, preferably a DMA controller **161** is included as being in communication with the imaging assembly **109**, the processing architecture **115** and the data storage means **122***b*. The DMA controller **161** can off-load the processor by transferring pixel data from the image sensor **106** directly to the single port memory **163** without involving the processing architecture **115** including the multi-core processor **116**. Accordingly, processor cycles that otherwise would be used to manage a frame buffer can instead be used to run decode **127**, **129** algorithms and/or otherwise as described above,

While the present invention substantially reduces the time required for a successful decode, it can also effectively manage the system clock and/or the power supplied to each core to reduce overall power consumption. Particularly in PDTs that are mostly powered by battery, power consumption is a concern because the greater the power dissipated, the faster the remaining battery life is reduced. Accordingly, and as shown in FIGS. **3** and **5**, a clock management module/logic **150** configured to dynamically vary the clock speed received by each respective core based on the workload/utilization of each core and/or a power management module/logic **150** configured to dynamically vary the voltage received by at least a portion of each core can be utilized to manage resources consumed by the multi-core processor **116***b*. One method of power management is described in U.S. patent application Ser. No. 11/238,489 to Borkar et al., incorporated herein by reference, as including voltage regulators to supply power to each core or a part of a core depending on a number of factors including activity, core temperature, transient current consumption, and reliability. Another method of power management has been described by Kim in U.S. patent application Ser. No. 11/424,080, incorporated herein by reference, which includes modulating the mode of the processor to single core or multi-core depending on a number of factors including whether the PDT is connected to AC or battery power, remaining battery level, available memory, and memory usage. One exemplary clock management module is disclosed by Naveh et al. in U.S. patent application Ser. No. 10/899,674, incorporated herein by reference, wherein the clock management module utilizes independent clock throttle settings for each core, independent clock throttle of various functional blocks of one or more core's internal architecture such as reorder buffers and reservation station tables, for example, and scaling the clock frequency of the bus that the multi-core processor uses to communicate with system components.

While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims.

I claim:

1. A portable data terminal, comprising:

at least one imaging assembly generating pixel data from a target;

a frame buffer receiving said pixel data from said imaging assembly;

a data storage means storing a plurality of program instructions implementing at least one one-dimensional decoder and at least one two-dimensional decoder,

a processor in communication with said data storage means and executing said program instructions such that said decoders decode said pixel data,

wherein said one dimensional decoder and said two dimensional decoder process, simultaneously and in parallel, a same frame of pixel data from said frame buffer on a first clock cycle until a successful decode occurs with either of said decoders; and

wherein, upon a successful decode, said decoders access, upon said first clock cycle, another frame of pixel data from said frame buffer.

2. The portable data terminal of claim **1**, wherein said processor is a multi-core processor.

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3. The portable data terminal of claim **2**, wherein said frame buffer is encompassed within a dual port memory accessed by said multicore processor.

4. The portable data terminal of claim **2** wherein the data storage means further includes at least one multi-port memory module having at least a first port and a second port, the at least one multi-port memory module being configured to transfer pixel data from said frame buffer to the multi-core processor.

5. The portable data terminal of claim **4**, wherein said multi-core processor comprises respective data caches receiving pixel data from respective first and second ports of said multi-port memory.

6. The portable data terminal of claim **4**, wherein said multi-core processor comprises a shared data cache receiving pixel data from said data storage means.

7. The portable data terminal of claim **1**, wherein said processor is a multi-core processor, and wherein the first core of the multi-core processor executes the one-dimensional decoder and the second core executes the two-dimensional decoder.

8. The portable data terminal of claim **1**, wherein said processor is a multi-core processor, and wherein a first core of the multi-core processor executes an image quality filter and a second core of the multi-core processor communicates with the network interface.

9. The portable data terminal of claim **8**, wherein the image quality filter is configured with filter program instructions that analyze pixel data received by the multi-core processor and assign an image quality score to the pixel data.

10. A portable data terminal, comprising:

at least one imaging assembly generating pixel data from a target;

a multi-core processor having at least a first core and a second core executing at least one one-dimensional decoder and at least one two-dimensional decoder;

at least one data cache in communication with said multi-core processor and receiving said pixel data such that said pixel data is accessible by both said one-dimensional and two-dimensional decoders;

wherein the one-dimensional decoder and two-dimensional decoder run in parallel to process the same pixel data on a first clock cycle, said first clock cycle terminating upon either of said decoders successfully decoding said same pixel data.

11. A portable data terminal according to claim **10**, wherein, upon each successful decode, said multi-core processor loads a successive frame of pixel data into said data cache at a frequency determined by said successful decodes or said first clock cycle.

12. A portable data terminal according to claim **10**, comprising:

a frame buffer storing pixel data from said imaging assembly prior to transferring said pixel data to said data cache.

13. A portable data terminal according to claim **10**, wherein said frame buffer receives pixel data on the same cycle as said pixel data is retrieved by said multi-core processor.

14. The portable data terminal of claim **10**, comprising a first level of cache and a second level of cache, the first level including an instruction cache and a data cache for each core and the second level being shared among all the cores.

15. The portable data terminal of claim **10**, wherein the multi-core processor comprises a third core and a fourth core executing an image quality filter and network access instructions.

16. A portable data terminal, comprising:

at least one imaging assembly generating pixel data from either a one dimensionally encoded target or a two dimensionally encoded target;

a memory receiving frames of said pixel data from the imaging assembly;

a multi-core processor configured to implement a one-dimensional decoder and a two dimensional decoder such that said decoders run in parallel, said processor further configured to direct a respective frame of pixel data to both of said decoders simultaneously;

wherein said imaging assembly continuously generates pixel data and said decoders process said frames of data at a frequency determined by successful decodes in either of said decoders.

17. The portable data terminal of claim **16**, comprising at least one management module selected from the group consisting of a clock management module configured to dynamically vary a clock speed received by respective first and second cores of said processor based on the workload of said respective cores and a power management module configured to dynamically vary the voltage received by at least a portion of each core.

18. The portable data terminal of claim **17**, wherein the multi-core processor comprises a third core and a fourth core, wherein the program instructions stored in the data storage means comprises an image quality filter and wherein the third core of the multi-core processor executes the image quality filter and the fourth core of the multi-core processor communicates with the network interface.

19. The portable data terminal of claim **16**, wherein said multi-core processor comprises either a data cache shared by said decoders or a respective data cache for each decoder.

20. The portable data terminal of claim **16**, wherein a first port of the memory is configured to receive at least one output signal from the imaging assembly, the output signals representing pixel data transmitted by the image sensor, and a second port of the memory is configured to communicate with the multi-core processor.

* * * * *

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≡ OPTICON

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11.30.2021

Financial Results for Third Quarter of Fiscal Year Ending November 30, 2022 (Consolidated)

September 22, 2022

Listed company name: Optoelectronics, Inc. Listed Exchange: Tokyo
Code No. 6664 URL :https://www.opto.co.jp/
Representative: Masami Tawara, President and Representative Director
Inquiries: Katsutoshi Ishikawa, Executive Officer, General Manager of Administration
Tel. 048-446-1181
Quarterly report scheduled filing date: September 22, 2022
Scheduled dividend payment date: --
Quarterly results supplementary material preparation: None
Quarterly results explanatory meeting: None

(Rounded down to nearest million yen)

1. Consolidated financial results for 3Q of FY ending 11.30.2022 (December 1, 2021 August 31, 2022)

(1) Consolidated Operating Results (cumulative)

(Percentages represent changes from the same period of the previous year)

	Sales		Ordinary Profit		Net Profit		Net income to parent co. shareholders	
	M ¥	%	M ¥	%	M ¥	%	M ¥	%
9 mos ending 11.2022	5, 453	△16. 7	375	△66. 5	223	△79. 6	149	△82. 7
9 mos ending 11.2022	6, 549	33. 5	1, 121	—	1, 096	—	864	—

(Note) Comprehensive income 3Q 11.2022 937 M¥ (Δ22.3%) 3Q 11.2021 1206 M¥ (-%)

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	4Q net profit/share	Diluted net income per share
	Yen Sen	Yen Sen
9 mos ending 11.2022	24. 17	—
9 mos ending 11.2022	139. 96	—

(2) Consolidated financial condition

	Combined Assets	Net Assets	Equity
	M¥	M¥	%
9 mos ending 11.2022	14, 407	5, 983	41. 5
11.2022 period	12, 769	5, 045	39. 5

(Ref.) Equity 9 mos ending 11.2022 5,983 M¥ 2021 Nov. Period 5,045 M¥

2 . Dividend status

	Annual Dividend Amount				
	1Q End	2Q End	3Q End	End of Period	Total
	Yen	Yen	Yen	Yen	Yen
11.2021 period	—	0. 00	—	0. 00	0. 00
11.2022 period	—	0. 00	—		
Ending 11.2022 (forecast)				0. 00	0. 00

(Note) Modifications based on recently published dividend forecasts: none

3. Consolidated Earnings Forecast for FY Ending 11.30.2022 (12.1, 2021-11.30, 2022)

(% shown is increase/decrease vs previous period)

	Sales		Operating Profit		Net Profit		Net income to parent co. shareholders		Net profit per share
	M¥	%	M¥	%	M¥	%	M¥	%	Yen Sen
Full year	7, 318	△12. 0	699	△40. 6	686	△40. 4	456	1. 8	73. 81

(Note) Recent modification from results forecasts: None

* Notes

(1) Significant movement of important subsidiaries in the current period consolidated cumulative

(2) Unique accounting procedures applied to creation of quarterly consolidated financial statements: no

(3) Changes in accounting policy/changes in accounting estimates/restatements

① Changes in accounting policy due to revisions in accounting standards, etc. : yes

② Changes in accounting policy other than ① : no

③ Changes in accounting estimates : no

④ Restatements : no

(Note) For details please see: "2. 4Q Consolidated Financial Statement and Principle Notes, (3) Notes Pertaining to Quarterly Financial Statements (Changes in Accounting Policy)."

(4) No. of shares issued (common stock)

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① No. of shares issued at end of period (including treasury shares)	11.2022 3Q	6, 578, 000 shares	11.2021	6, 578, 000 shares
② No. of treasury stock shares at end of period	11.2022 3Q	400, 047 shares	11.2021	400, 047 shares
③ Average no. of shares in period	11.2022 3Q	6, 177, 953 shares	11.2021 3Q	6, 177, 953 shares

* Quarterly results are not subject to review by certified public accountants or audit firms.

* Explanation of appropriate use of earnings forecasts; other special instructions.
Statements of details such as results forecasts herein reflect judgments based on currently available information and include significant uncertainties. Actual results may differ greatly due to changes in conditions, etc. The company makes no representations as to the likelihood of forecast realization.

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Optoelectronics, Inc. (6664) Financial Results for the Third Quarter of the Fiscal Year Ending November 30, 2022

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(Optoelectronics, Inc. (6664) Financial Results for the Third Quarter of the Fiscal Year Ending November 30, 2022

1. Qualitative information regarding the current quarter results

(1) Explanation of business performance

During the current consolidated cumulative third quarter (December 1, 2021 to August 31, 2022), the world economy has been stagnant due to circumstances in Russia and Ukraine, as prices have risen rapidly. The outlook for manufacturing is also uncertain due to production stoppages, delivery delays, and rising procurement costs caused by tight supply and demand for semiconductor parts and soaring raw material prices. During the current 3Q, group sales and profits decreased compared to the same period of the previous year. Net sales for the current 3Q consolidated cumulative period were ¥5,453 million (down 16.7% year-on-year). Broken out by segment, Japan sales were ¥2,274 million (down 3.2% year-on-year), US sales were ¥1,114 million (down 50.9% year-on-year), and Europe, Asia, and other sales were ¥2,063 million (up 6.9% year-on-year).

Within Japan, sales of handy scanners and stationary scanners increased compared to the previous fiscal year, however overall sales decreased due to delivery delays caused by parts shortages and postponement of projects due to customer circumstances.

Overseas, sales in the United States fell sharply compared to the previous year due to termination of special demand project(s) in the previous fiscal year. In Europe, Asia and other regions, sales increased year-on-year in some regions such as Italy, France and Germany.

On the profit side, operating income was ¥375 million (down 66.5% year-on-year), ordinary income was ¥223 million (down 79.6% year-on-year), and net income returned to parent company shareholders was ¥1. 49 million (down 82.7% year-on-year). This was mainly due to a decrease in margins on products due to the steep rise in raw material prices.

Calculations in the current third quarter consolidated cumulative period are made using an exchange rate of 1 US dollar = ¥121.07 and 1 Euro = ¥133.63.

(3) Explanation of future forecast information such as consolidated earnings forecasts

There are currently no changes to the earnings forecast announced December 23, 2021.

Prices are also rising rapidly around the world, and shortages of prices rises for semiconductor parts and have led to decreased sales and increased cost of sales due to delivery delays. We are currently continuing shipments and sales with minimal impact, but the situation regarding business performance demands vigilance.

We intend to promptly disclose any needed revisions to results forecasts according to circumstances.

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Optoelectronics, Inc. (6664) Financial Results for the Third Quarter of the Fiscal Year Ending November 30, 2022

2. Consolidated financial statement and notes for quarter

(1) Consolidated balance sheet for quarter

(Unit: ¥1000)

	Previous consolidated FY (11.30.2021)	当第３四半期連結会計期間 (2022年８月31日)
Assets		
Current		
Cash and Deposits	5, 835, 051	6, 099, 823
Notes and accounts receivable	1, 498, 446	1, 675, 885
Goods and products	1, 135, 866	1, 412, 070
Work in progress	144, 613	93, 908
Raw materials and supplies	718, 708	1, 378, 194
Other	417, 426	689, 919
Bad loan reserves	△49, 874	△52, 974
Total current assets	9, 700, 238	11, 296, 827
Fixed Assets		
Tangible fixed assets		
Buildings and structures (net)	1, 439, 662	1, 419, 857
Machinery and delivery equipment (net)	114, 086	97, 712
Tools, instruments, and equipment (net)	136, 570	114, 731
Land	554, 178	554, 178
Lease assets (net)	8, 951	6, 265
Construction in progress	9, 298	47, 897
Total tangible fixed assets	2, 262, 748	2, 240, 644
Intangible fixed assets		
Other	287, 651	275, 499
Intangible fixed assets total	287, 651	275, 499
Investments and other assets		
Investment securities	3, 327	3, 868
Deferred tax assets	372, 761	435, 914
Other	143, 236	154, 902
Total investments and other assets	519, 324	594, 685
Total fixed assets	3, 069, 725	3, 110, 829
Total assets	12, 769, 963	14, 407, 656

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Optoelectronics, Inc. (6664) Financial Results for the Third Quarter of the Fiscal Year Ending November 30, 2022

(Unit: ¥1000)

	Previous consolidated FY (11.30.2021)	Current 3Q consolidated FY period (8.31.2022)
Liabilities		
Current Liabilities		
Notes payable, accounts payable	426, 778	963, 870
Short term borrowing	163, 337	133, 340
Long term borrowing scheduled for repayment within 1 year	2, 306, 730	2, 186, 244
Corporate taxes owed, etc.	87, 806	38, 907
Reserve for bonuses	—	29, 741
Reserve for litigation losses	640, 000	785, 000
Other	437, 897	572, 034
Total current liabilities	4, 062, 550	4, 709, 137
Fixed Debt		
Long term borrowing	3, 619, 096	3, 675, 134
Lease obligations	6, 070	3, 061
Deferred tax liabilities	30, 786	30, 821
Other	5, 713	6, 277
Total fixed debt	3, 661, 666	3, 715, 294
Total debt	7, 724, 216	8, 424, 432
Net Assets		
Shareholder equity		
Capital	942, 415	942, 415
Capital surplus	219, 136	219, 136
Earned surplus	4, 401, 764	4, 551, 068
Treasury stock	△212, 441	△212, 441
Total shareholder equity	5, 350, 873	5, 500, 178
Other accumulated comprehensive income		
Valuation difference on other securities	△170	370
Currency conversion adjustment account	△304, 955	482, 674
Total comprehensive income accumulated amount	△305, 126	483, 045
Total net assets	5, 045, 747	5, 983, 223
Total Liabilities and Equity	12, 769, 963	14, 407, 656

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2. Quarterly Consolidated Statements of Income and Comprehensive Income
(Quarterly consolidated income statement)
(3Q consolidated cumulative period)

(Unit: ¥1000)

	Previous 3Q consolidated cumulative period (12.1.2020 to 8.31.2021)	Current 3Q consolidated cumulative period (12.1.2021 to 8.31.2022)
Sales	6, 549, 937	5, 453, 848
Cost of sales	3, 587, 457	3, 170, 748
Gross profit on sales	2, 962, 480	2, 283, 099
Selling, general, and admin. expense	1, 840, 989	1, 907, 696
Operating income	1, 121, 490	375, 403
Non-operating income		
Interest income	973	3, 127
Rents received	14, 055	10, 460
Other	5, 349	730
Total non-operating income	20, 378	14, 319
Non-operating expenses		
Interest paid	27, 306	31, 569
Exchange losses	—	123, 283
Loss on disposal of fixed assets	980	2, 384
Commissions paid	17, 545	9, 023
Other	1	—
Total non-operating expenses	45, 833	166, 261
Ordinary income	1, 096, 035	223, 461
Net quarterly profit before taxes	1, 096, 035	223, 461
Corporate, resident, and business taxes	210, 187	65, 301
Corporate tax adjustment amount	21, 211	8, 855
Total corporate and other taxes	231, 398	74, 156
Quarterly net profit	864, 637	149, 304
Quarterly profits to shareholders of parent company	864, 637	149, 304

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(Quarterly Consolidated Statement of Comprehensive Income)
(3Q Consolidated Cumulative Period)

Unit: ¥1000

	Previous 3Q consolidated cumulative period (12.1.2020 to 8.31.2021)	Current 3Q consolidated cumulative period (12.1.2021 to 8.31.2022)
Quarterly net income	864, 637	149, 304
Other comprehensive income		
Other valuation differences on securities	343	541
Foreign currency exchange adjustment account	341, 732	787, 630
Total other comprehensive income	342, 076	788, 172
Quarterly comprehensive income	1, 206, 713	937, 476
(Breakdown)		
Quarterly comprehensive income pertaining to parent company shareholders	1, 206, 713	937, 476

(3) Notes on quarterly consolidated financial statements
(Notes regarding going concern assumptions)
No applicable items.

(Notes on extraordinary fluctuations in shareholder equity)
No applicable items.

(Changes in accounting policies)
(Application of accounting standards for revenue recognition)

"Accounting Standard for Revenue Recognition" (ASBJ Statement No. 29, 3.31.2020; "Revenue Recognition Accounting Standard" below) has been applied from the start of the 1Q consolidated accounting period, and we made a determination to recognize revenue in the amount expected to be received for goods or services as of the transfer of control of promised goods or services to a customer. Thus for chargeable supply transactions for which it is judged that the company has a substantial repurchase obligation, [the company] continues to recognize inventory assets as financial transactions, and recognizes a financial liability for end of period inventory amounts for supplied goods remaining at the [premises] of the supply recipient being charged.

The application of revenue recognition accounting standards, etc. follows the transitional treatment stipulated in the provisos of paragraph 84 of the revenue recognition accounting standard; the cumulative effects when new accounting policies are retroactively applied before the beginning of the first quarter consolidated accounting period are added to or subtracted from retained earnings at the beginning of the first quarter consolidated accounting period, and the new accounting policy applied to the balance at the start of the subject period, however no adjustment is made to the balance of retained earnings at the beginning of the period, given that the effect of retained earnings on balances at the beginning of said period is minor.

The impact of applying the revenue recognition accounting standard to P/L for the current 3Q consolidated cumulative period is therefore minor.

(Application of accounting standards, etc. on the calculation of market price)

"Accounting standards for the calculation of market prices" (ASBJ Standard No. 30, July 4, 2019; "Market Value Accounting Standards" below) and the like are applied from the start of the period for the 1Q consolidated accounting period and, in accordance with the transitional treatment set forth in Market Value Accounting Standards, Par. 19, and "Accounting Standards for Financial Instruments" (Corporate Accounting Standard No. 10, July 4, 2019) Par. 44-2, it has been determined that new accounting policies under the Market Value Accounting Standards will be applied in future. This will have no impact on quarterly consolidated financial statements.

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Optoelectronics, Inc. (6664) Financial Results for the Third Quarter of the Fiscal Year Ending November 30, 2022

(Segment information, etc.)

[Segment Information]

I Previous consolidated cumulative 3Q (December 1, 2020 to August 31, 2021)

1 Information on sales and profit or loss amounts for each reported segment.

(Unit: ¥1000)

	Reported Segment				Adjustment Amount (Note 1)	Quarterly Consolidated P/L Calculation Sheet Reported Amount (Note 2)
	Japan	US	Europe, Asia, Other	Total		
Sales (1) Sales to external customers	2, 349, 723	2, 270, 299	1, 929, 914	6, 549, 937	—	6, 549, 937
(2) Internal sales or transfers between segments	916, 422	59, 055	746, 029	1, 721, 507	△1, 721, 507	—
Total	3, 266, 146	2, 329, 354	2, 675, 944	8, 271, 445	△1, 721, 507	6, 549, 937
Segment Profit	332, 919	541, 472	220, 960	1, 095, 352	26, 138	1, 121, 490

(Notes)

1. Segment profit adjustments are deletions of transactions between segments.
2. Segment profits have been adjusted with the operating income [listed] in the quarterly consolidated income statement.

2. Information such as fixed asset impairment losses, goodwill, etc. for each reporting segment: No applicable items.

II Current consolidated cumulative 3Q (December 1, 2021 to August 31, 2022)

1 Information on the amount of sales and profit or loss by reporting segment, and information about division of profits

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(Unit: ¥1000)

	Reported Segment				Adjustment Amount (Note 1)	Quarterly Consolidated P/L Calculation Sheet Reported Amount (Note 2)
	Japan	US	Europe, Asia, Other	Total		
Sales Revenue from contracts w customers	2, 274, 991	1, 114, 987	2, 063, 869	5, 453, 848	—	5, 453, 848
(1) Sales to external customers	2, 274, 991	1, 114, 987	2, 063, 869	5, 453, 848	—	5, 453, 848
(2) Internal sales or transfers between segments	661, 603	128, 791	219, 224	1, 009, 619	△1, 009, 619	—
Total	2, 936, 594	1, 243, 778	2, 283, 094	6, 463, 467	△1, 009, 619	5, 453, 848
Segment Profit or Loss (delta)	177, 314	△9, 451	219, 986	387, 850	△12, 446	375, 403

(Notes)

1. The amount of adjustment to segment profit or loss (Δ) deletes transactions between segments.
2. Segment profits or losses (Δ) are adjusted with the quarterly consolidated income statement operating income.

2. Items pertaining to changes, etc. in reporting segments

As noted in accounting policy changes, because accounting standards for revenue recognition, etc. are applied from the start of the 1Q consolidated accounting period, and the accounting method for revenue recognition was changed, [we] have similarly changed the method for calculation of profit or loss of business segments, however the effect [thereof] on segment profit or loss (Δ) is minor.

3. Information pertaining to impairment losses for fixed assets or goodwill, etc. for each reporting segment.

No applicable items.

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American Translators Association
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Christopher L. Field
Japanese into English
Certification #423514
Certified Translator

Verify at www.atanet.org/verify

CERTIFICATION OF TRANSLATION

I, Christopher L. Field, residing at 52 Sherman's Bridge Rd., Wayland MA, 01778, United States of America, declare and state as follows:

I am well acquainted with the English and Japanese languages. I have translated numerous Japanese documents of legal and/or technical content into English. I am fully accredited by the American Translators Association (ATA) for Japanese to English translation, and my ATA certification number is 423514.

I have personally translated the attached document, entitled **"3Q JASDAQ regulatory filing dated 9-22-22"** from Japanese into English. I hereby certify that the English translation of the attached documents is an accurate translation to the best of my knowledge and ability.

I further declare that all statements made herein of my own knowledge are true, that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed at West Tisbury, Massachusetts, 10 July, 2023.

Signed,________________________

Christopher Field

ATA Certified Translator, Japanese to English, Certificate No. 423514

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JPX 東証JASDAQ上場

2022年11月期　第３四半期決算短信〔日本基準〕（連結）

2022年９月22日

上場会社名　株式会社オプトエレクトロニクス　上場取引所　東
コード番号　6664　ＵＲＬ　https://www.opto.co.jp/
代表者　（役職名）代表取締役社長　（氏名）俵　政美
問合せ先責任者　（役職名）執行役員管理部部長　（氏名）石川　勝利　ＴＥＬ　048-446-1181
四半期報告書提出予定日　2022年９月22日　配当支払開始予定日　－
四半期決算補足説明資料作成の有無：無
四半期決算説明会開催の有無　：無

（百万円未満切捨て）

１．2022年11月期第３四半期の連結業績（2021年12月１日～2022年８月31日）

（１）連結経営成績（累計）　（%表示は、対前年同四半期増減率）

	売上高		営業利益		経常利益		親会社株主に帰属する四半期純利益	
	百万円	%	百万円	%	百万円	%	百万円	%
2022年11月期第３四半期	5,453	△16.7	375	△66.5	223	△79.6	149	△82.7
2021年11月期第３四半期	6,549	33.5	1,121	－	1,096	－	864	－

（注）包括利益　2022年11月期第３四半期　937百万円（△22.3%）　2021年11月期第３四半期　1,206百万円（－%）

	１株当たり四半期純利益	潜在株式調整後１株当たり四半期純利益
	円 銭	円 銭
2022年11月期第３四半期	24.17	－
2021年11月期第３四半期	139.96	－

（２）連結財政状態

	総資産	純資産	自己資本比率
	百万円	百万円	%
2022年11月期第３四半期	14,407	5,983	41.5
2021年11月期	12,769	5,045	39.5

（参考）自己資本　2022年11月期第３四半期　5,983百万円　2021年11月期　5,045百万円

２．配当の状況

	年間配当金				
	第１四半期末	第２四半期末	第３四半期末	期末	合計
	円 銭	円 銭	円 銭	円 銭	円 銭
2021年11月期	－	0.00	－	0.00	0.00
2022年11月期	－	0.00	－		
2022年11月期（予想）				0.00	0.00

（注）直近に公表されている配当予想からの修正の有無：無

３．2022年11月期の連結業績予想（2021年12月１日～2022年11月30日）

（%表示は、対前期増減率）

	売上高		営業利益		経常利益		親会社株主に帰属する当期純利益		１株当たり当期純利益
	百万円	%	百万円	%	百万円	%	百万円	%	円 銭
通期	7,318	△12.0	699	△40.6	686	△40.4	456	1.8	73.81

（注）直近に公表されている業績予想からの修正の有無：無

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※　注記事項

（１）当四半期連結累計期間における重要な子会社の異動（連結範囲の変更を伴う特定子会社の異動）：無

（２）四半期連結財務諸表の作成に特有の会計処理の適用：無

（３）会計方針の変更・会計上の見積りの変更・修正再表示

①　会計基準等の改正に伴う会計方針の変更　：有

②　①以外の会計方針の変更　：無

③　会計上の見積りの変更　：無

④　修正再表示　：無

（注）詳細は、添付資料７ページ「２．四半期連結財務諸表及び主な注記（３）四半期連結財務諸表に関する注記事項（会計方針の変更）」をご覧ください。

（４）発行済株式数（普通株式）

①　期末発行済株式数（自己株式を含む）	2022年11月期３Ｑ	6,578,000株	2021年11月期	6,578,000株
②　期末自己株式数	2022年11月期３Ｑ	400,047株	2021年11月期	400,047株
③　期中平均株式数（四半期累計）	2022年11月期３Ｑ	6,177,953株	2021年11月期３Ｑ	6,177,953株

※　四半期決算短信は公認会計士又は監査法人の四半期レビューの対象外です

※　業績予想の適切な利用に関する説明、その他特記事項

本資料に記載されている業績見通し等の詳細に関する記述は、現時点で入手可能な情報に基づき判断した見通しであり、多分に不確定な要素を含んでおります。また、実際の業績は業況の変化等により大きく異なる可能性があります。当社としてその実現を約束する趣旨のものではありません。

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１．当四半期決算に関する定性的情報

（１）経営成績に関する説明

当第３四半期連結累計期間（2021年12月１日～2022年８月31日）は、ロシア・ウクライナ情勢等により世界経済が停滞する一方、物価上昇が急速に進んでおります。製造業においても、半導体部品等の需給逼迫及び原材料価格の高騰により、生産停止、納期遅延、調達価格の上昇等の影響を受け、先行きが不透明な状況となっております。

当第３四半期連結累計期間における当社グループは、前年同期比にて減収減益となりました。

当第３四半期連結累計期間の売上高は、54億53百万円（前年同期比16.7%減）となりました。

セグメントの内訳を示しますと、日本では22億74百万円（前年同期比3.2%減）、米国は11億14百万円（前年同期比50.9%減）、欧州・アジア他は20億63百万円（前年同期比6.9%増）となりました。

日本国内においては、ハンディスキャナ及び定置式スキャナが前年度比で売上増となりましたが、部品逼迫による納期遅延や顧客都合による案件の延期等が継続しており、全体で売上減となりました。

海外においては、米国では前年度の特需案件の終了により前年度比で大幅な売上減となりました。欧州・アジア他では、イタリア・フランス・ドイツ等の一部地域において前年度比で売上増となりました。

利益面では、営業利益が３億75百万円（前年同期比66.5%減）、経常利益が２億23百万円（前年同期比79.6%減）、親会社株主に帰属する四半期純利益が１億49百万円（前年同期比82.7%減）となりました。原材料等の価格高騰により、製品の利益率が低下したことが主な要因であります。

なお、当第３四半期連結累計期間においての為替レートは、１ドル＝121.07円、１ユーロ＝133.63円で算出しております。

（２）財政状態に関する説明

当第３四半期連結会計期間末の総資産は144億７百万円となり、前連結会計年度末と比較して16億37百万円の増加となりました。主な要因は、製品在庫を確保するために商品及び製品が２億76百万円増加したこと及び部品在庫の確保並びに原材料価格の高騰に伴い原材料及び貯蔵品が６億59百万円増加したこと等により、流動資産合計が15億96百万円増加したことによるものです。

負債は84億24百万円となり前連結会計年度末と比較して７億円増加となりました。主な要因は、支払手形及び買掛金が５億37百万円増加したこと及び訴訟損失引当金が１億45百万円増加したこと等により流動負債合計が６億46百万円増加したことによるものです。

なお、純資産は59億83百万円となり、前連結会計年度末と比較して９億37百万円増加いたしました。

（３）連結業績予想などの将来予測情報に関する説明

現在のところ、2021年12月23日に公表した業績予想からの変更はございません。

なお、世界的に物価上昇が急速に進んでおり、半導体部品の不足や価格高騰等の影響を受け、納期遅延等に伴う売上の減少及び原価率の上昇等が発生しております。現在は影響を最低限にとどめ出荷及び販売を継続しておりますが、業績については予断を許さない状況となっております。

今後の状況により、新たに業績予想の修正が必要となった場合には、速やかに開示する予定であります。

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２．四半期連結財務諸表及び主な注記

（１）四半期連結貸借対照表

（単位：千円）

	前連結会計年度 （2021年11月30日）	当第３四半期連結会計期間 （2022年８月31日）
資産の部		
流動資産		
現金及び預金	5, 835, 051	6, 099, 823
受取手形及び売掛金	1, 498, 446	1, 675, 885
商品及び製品	1, 135, 866	1, 412, 070
仕掛品	144, 613	93, 908
原材料及び貯蔵品	718, 708	1, 378, 194
その他	417, 426	689, 919
貸倒引当金	△49, 874	△52, 974
流動資産合計	9, 700, 238	11, 296, 827
固定資産		
有形固定資産		
建物及び構築物（純額）	1, 439, 662	1, 419, 857
機械装置及び運搬具（純額）	114, 086	97, 712
工具、器具及び備品（純額）	136, 570	114, 731
土地	554, 178	554, 178
リース資産（純額）	8, 951	6, 265
建設仮勘定	9, 298	47, 897
有形固定資産合計	2, 262, 748	2, 240, 644
無形固定資産		
その他	287, 651	275, 499
無形固定資産合計	287, 651	275, 499
投資その他の資産		
投資有価証券	3, 327	3, 868
繰延税金資産	372, 761	435, 914
その他	143, 236	154, 902
投資その他の資産合計	519, 324	594, 685
固定資産合計	3, 069, 725	3, 110, 829
資産合計	12, 769, 963	14, 407, 656

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（単位：千円）

	前連結会計年度 (2021年11月30日)	当第３四半期連結会計期間 (2022年８月31日)
負債の部		
流動負債		
支払手形及び買掛金	426, 778	963, 870
短期借入金	163, 337	133, 340
１年内返済予定の長期借入金	2, 306, 730	2, 186, 244
未払法人税等	87, 806	38, 907
賞与引当金	－	29, 741
訴訟損失引当金	640, 000	785, 000
その他	437, 897	572, 034
流動負債合計	4, 062, 550	4, 709, 137
固定負債		
長期借入金	3, 619, 096	3, 675, 134
リース債務	6, 070	3, 061
繰延税金負債	30, 786	30, 821
その他	5, 713	6, 277
固定負債合計	3, 661, 666	3, 715, 294
負債合計	7, 724, 216	8, 424, 432
純資産の部		
株主資本		
資本金	942, 415	942, 415
資本剰余金	219, 136	219, 136
利益剰余金	4, 401, 764	4, 551, 068
自己株式	△212, 441	△212, 441
株主資本合計	5, 350, 873	5, 500, 178
その他の包括利益累計額		
その他有価証券評価差額金	△170	370
為替換算調整勘定	△304, 955	482, 674
その他の包括利益累計額合計	△305, 126	483, 045
純資産合計	5, 045, 747	5, 983, 223
負債純資産合計	12, 769, 963	14, 407, 656

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（２）四半期連結損益計算書及び四半期連結包括利益計算書

（四半期連結損益計算書）

（第３四半期連結累計期間）

（単位：千円）

	前第３四半期連結累計期間 （自　2020年12月１日 至　2021年８月31日）	当第３四半期連結累計期間 （自　2021年12月１日 至　2022年８月31日）
売上高	6, 549, 937	5, 453, 848
売上原価	3, 587, 457	3, 170, 748
売上総利益	2, 962, 480	2, 283, 099
販売費及び一般管理費	1, 840, 989	1, 907, 696
営業利益	1, 121, 490	375, 403
営業外収益		
受取利息	973	3, 127
受取賃貸料	14, 055	10, 460
その他	5, 349	730
営業外収益合計	20, 378	14, 319
営業外費用		
支払利息	27, 306	31, 569
為替差損	－	123, 283
固定資産除却損	980	2, 384
支払手数料	17, 545	9, 023
その他	1	－
営業外費用合計	45, 833	166, 261
経常利益	1, 096, 035	223, 461
税金等調整前四半期純利益	1, 096, 035	223, 461
法人税、住民税及び事業税	210, 187	65, 301
法人税等調整額	21, 211	8, 855
法人税等合計	231, 398	74, 156
四半期純利益	864, 637	149, 304
親会社株主に帰属する四半期純利益	864, 637	149, 304

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（四半期連結包括利益計算書）
（第３四半期連結累計期間）

（単位：千円）

	前第３四半期連結累計期間 （自　2020年12月１日 至　2021年８月31日）	当第３四半期連結累計期間 （自　2021年12月１日 至　2022年８月31日）
四半期純利益	864,637	149,304
その他の包括利益		
その他有価証券評価差額金	343	541
為替換算調整勘定	341,732	787,630
その他の包括利益合計	342,076	788,172
四半期包括利益	1,206,713	937,476
（内訳）		
親会社株主に係る四半期包括利益	1,206,713	937,476

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（３）四半期連結財務諸表に関する注記事項

（継続企業の前提に関する注記）

該当事項はありません。

（株主資本の金額に著しい変動があった場合の注記）

該当事項はありません。

（会計方針の変更）

(収益認識に関する会計基準等の適用)

「収益認識に関する会計基準」（企業会計基準第29号　2020年３月31日。以下「収益認識会計基準」という。）等を第１四半期連結会計期間の期首から適用し、約束した財又はサービスの支配が顧客に移転した時点で、当該財又はサービスと交換に受け取ると見込まれる金額で収益を認識することといたしました。これにより、当社が実質的に買戻し義務を負っていると判断される有償支給取引について、金融取引として棚卸資産を引き続き認識するとともに、有償支給先に残存する支給品の期末棚卸高について金融負債を認識しております。

収益認識会計基準等の適用については、収益認識会計基準第84項ただし書きに定める経過的な取扱いに従っており、第１四半期連結会計期間の期首より前に新たな会計方針を遡及適用した場合の累積的影響額を、第１四半期連結会計期間の期首の利益剰余金に加減し、当該期首残高から新たな会計方針を適用しておりますが、利益剰余金の当期首残高への影響が軽微であることから、期首の利益剰余金残高の調整を行っておりません。

この結果、収益認識会計基準等の適用が当第３四半期連結累計期間の損益に与える影響は軽微であります。

(時価の算定に関する会計基準等の適用)

「時価の算定に関する会計基準」（企業会計基準第30号　2019年７月４日。以下「時価算定会計基準」という。）等を第１四半期連結会計期間の期首から適用し、時価算定会計基準第19項及び「金融商品に関する会計基準」（企業会計基準第10号　2019年７月４日）第44－２項に定める経過的な取扱いに従って、時価算定会計基準等が定める新たな会計方針を、将来にわたって適用することといたしました。これによる四半期連結財務諸表に与える影響はありません。

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（セグメント情報等）

【セグメント情報】

Ⅰ　前第３四半期連結累計期間（自　2020年12月１日　至　2021年８月31日）

１　報告セグメントごとの売上高及び利益又は損失の金額に関する情報

（単位：千円）

	報告セグメント				調整額（注1）	四半期連結損益計算書計上額（注2）
	日本	米国	欧州・アジア他	合計		
売上高						
（1）外部顧客への売上高	2,349,723	2,270,299	1,929,914	6,549,937	－	6,549,937
（2）セグメント間の内部売上高又は振替高	916,422	59,055	746,029	1,721,507	△1,721,507	－
計	3,266,146	2,329,354	2,675,944	8,271,445	△1,721,507	6,549,937
セグメント利益	332,919	541,472	220,960	1,095,352	26,138	1,121,490

（注）1. セグメント利益の調整額は、セグメント間の取引消去であります。

2. セグメント利益は、四半期連結損益計算書の営業利益と調整を行っております。

２．報告セグメントごとの固定資産の減損損失又はのれん等に関する情報

該当事項はありません。

Ⅱ　当第３四半期連結累計期間（自　2021年12月１日　至　2022年８月31日）

１　報告セグメントごとの売上高及び利益又は損失の金額に関する情報並びに収益の分解情報

（単位：千円）

	報告セグメント				調整額（注1）	四半期連結損益計算書計上額（注2）
	日本	米国	欧州・アジア他	合計		
売上高						
顧客との契約から生じる収益	2,274,991	1,114,987	2,063,869	5,453,848	－	5,453,848
（1）外部顧客への売上高	2,274,991	1,114,987	2,063,869	5,453,848	－	5,453,848
（2）セグメント間の内部売上高又は振替高	661,603	128,791	219,224	1,009,619	△1,009,619	－
計	2,936,594	1,243,778	2,283,094	6,463,467	△1,009,619	5,453,848
セグメント利益又は損失（△）	177,314	△9,451	219,986	387,850	△12,446	375,403

（注）1. セグメント利益又は損失（△）の調整額は、セグメント間の取引消去であります。

2. セグメント利益又は損失（△）は、四半期連結損益計算書の営業利益と調整を行っております。

２．報告セグメントの変更等に関する事項

会計方針の変更に記載のとおり、第１四半期連結会計期間の期首から収益認識会計基準等を適用し、収益認識に関する会計処理方法を変更したため、事業セグメントの利益又は損失の算定方法を同様に変更しておりますが、セグメント利益又は損失（△）に与える影響は軽微であります。

３．報告セグメントごとの固定資産の減損損失又はのれん等に関する情報

該当事項はありません。

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IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF NORTH CAROLINA
CHARLOTTE DIVISION

HONEYWELL INTERNATIONAL INC., HAND HELD PRODUCTS, INC., and METROLOGIC INSTRUMENTS, INC., Plaintiffs, v. OPTO ELECTRONICS CO., LTD., Defendant	Case No. 3:21-cv-00506 JURY TRIAL DEMANDED

DEFENDANT'S OBJECTIONS AND RESPONSES TO PLAINTIFFS' FIRST SET OF REQUESTS FOR ADMISSION

Pursuant to Federal Rule of Civil Procedure 36, Defendant OPTO Electronics Co., Ltd. ("OPTO") provides these objections and responses to Plaintiffs Honeywell International Inc.'s; Hand Held Products, Inc.'s; and Metrologic Instruments, Inc.'s (collectively, "Honeywell's" or "Plaintiffs'") First Set of Requests for Admission ("Requests").

PRELIMINARY STATEMENT

OPTO has not yet completed its investigation of the facts relating to this action, its preparation for trial, or associated discovery. As discovery proceeds, OPTO may discover facts, information, evidence, documents and/or things that are not set forth herein, but which may be responsive to these Requests. These objections and responses are based on OPTO's present knowledge, information, and belief, and are complete to the best of OPTO's knowledge at this time.

Furthermore, OPTO has prepared these objections and responses based on its good-faith interpretation and understanding of the individual Requests. OPTO expressly reserves its right to correct any inadvertent errors or omissions. OPTO also reserves the right to conduct discovery with reference to or to offer evidence at the time of trial of any facts, evidence, documents, and things developed during discovery and trial preparation, notwithstanding the reference to certain facts, evidence, documents, and things in these objections and responses. Additionally, OPTO reserves the right to revise and supplement these objections and responses based on any information, evidence, and documentation that may be discovered after the service of these objections and responses, as appropriate. OPTO is not waiving, and expressly preserves, any and all objections to relevance, admissibility, or authenticity of any documents or information produced in conjunction herewith.

GENERAL OBJECTIONS

1. OPTO objects to the Requests to the extent that they seek to impose obligations beyond or inconsistent with those required by the Federal Rules of Civil Procedure, the Local Rules of the United States District Court for the Western District of North Carolina (the "Court"), any orders of the Court, or any stipulations or agreements of the parties.

2. OPTO objects to the Requests, including all definitions and instructions provided therein, to the extent that they would require OPTO to reach legal conclusions in order to respond.

3. OPTO objects to the Requests to the extent they call for information protected from disclosure by the attorney-client privilege, attorney work-product doctrine, or any other applicable privilege. Should any such disclosure by OPTO occur, it is inadvertent and shall not constitute a waiver of any privilege.

4. OPTO objects to the Requests to the extent that they seek trade secrets, research and development information, proprietary or confidential business or financial information, business plans or marketing information, or any other highly sensitive or confidential commercial information that is subject to protection under state or federal law or is otherwise within the protections of Rule 26(c) of the Federal Rules of Civil Procedure. To the extent that OPTO agrees to produce such information, or documents containing or reflecting such information, OPTO's production will be subject to the Protective Order entered in this Action.

5. OPTO objects to the Requests to the extent they require OPTO to marshal all of its evidence while discovery is ongoing.

6. OPTO objects to the definition of "Relevant Time Period" to the extent that the defined time period is overbroad as applied, and therefore unduly burdensome, and to the extent that it imposes obligations beyond or inconsistent with those required by the Federal Rules of Civil Procedure, the Local Rules of the Court, any orders of the Court, or any stipulations or agreement of the parties.

7. OPTO objects to the definition of "OPTO," "You," and "Your" as overbroad to the extent that it includes entities not involved in this action and not under the direction or control of OPTO.

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RESPONSES AND SPECIFIC OBJECTIONS TO PLAINTIFFS'
FIRST SET OF REQUESTS FOR ADMISSION

[redacted]

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[redacted]

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[redacted]

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ADMISSION REQUEST NO. 4

Admit that PDF417 is a "continuous, multi-row two-dimensional" code type as defined in ISO/IEC 15438:2006.

RESPONSE:

OPTO specifically objects to this Request as premature as discovery is currently ongoing, and therefore OPTO has not formulated its final contentions regarding OPTO's claims and defenses in this case. OPTO accordingly reserves its right to supplement and/or amend its response as the record is developed through discovery. OPTO also objects to this Request to the extent it seeks information protected by the attorney-client privilege, work product protection, or any other privilege applicable by law. Subject to and without waiving the foregoing General and specific objections, OPTO states as follows:

Admitted that PDF417 is a continuous, multi-row two-dimensional code type symbol that is constructed graphically as a series of rows of symbol characters, representing data and overhead components, placed in a defined vertical arrangement to form a (normally) rectangular symbol, which contains a single data message so that each symbol character has the characteristics of a linear bar code symbol character, and each row has those of a linear bar code symbol as defined in ISO/IEC 15438:2006 and ISO/IEC 15415:2011.

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(54) **OPTICAL READER SYSTEM COMPRISING LOCAL HOST PROCESSOR AND OPTICAL READER**

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See application file for complete search history.

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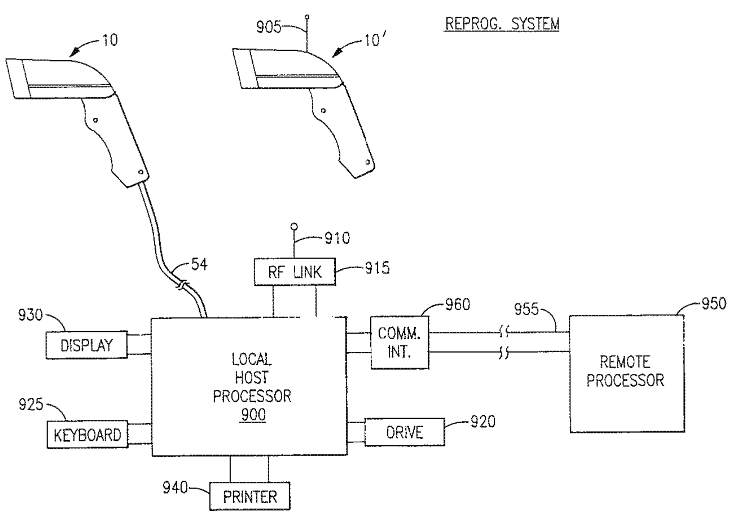
(57) **ABSTRACT**

In an optical reading system comprising an optical reader and a host processor, the host processor may be configured to transmit a component control instruction in response to a user input command input by a user of the host processor to remotely control the reader. The optical reader subsequently receives the transmitted component control instruction and executes the component control instruction substantially on receipt thereof.

62 Claims, 32 Drawing Sheets



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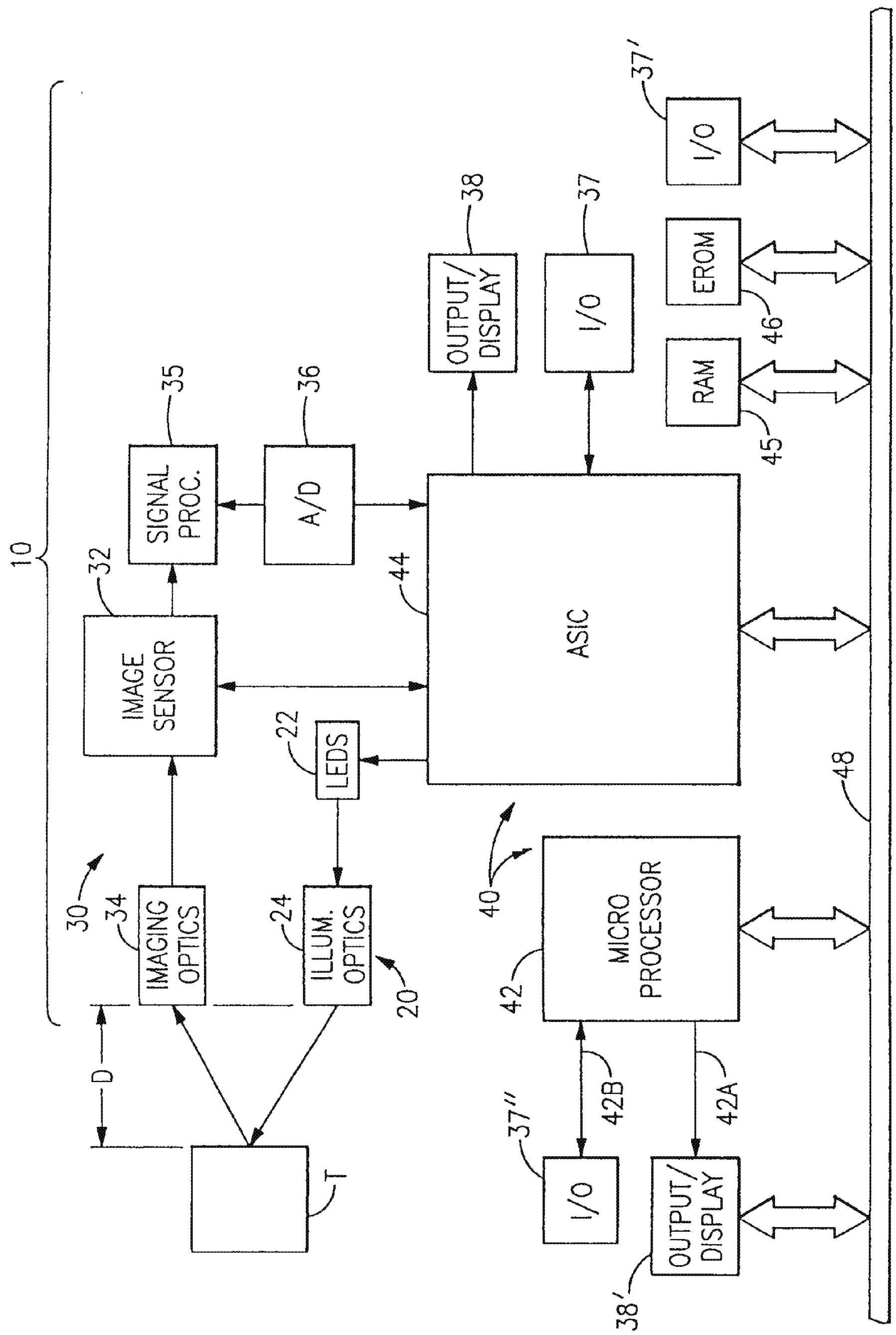
10
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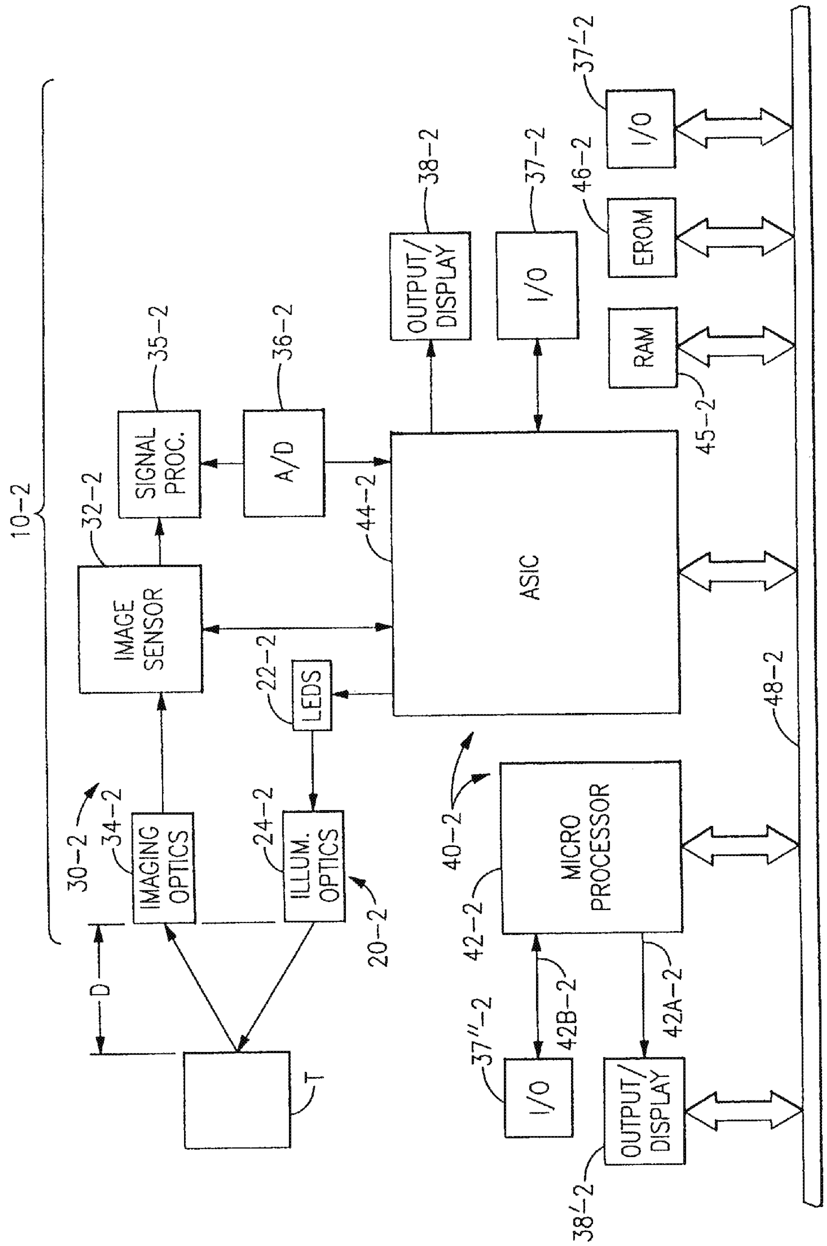
32
SIGNAL PROC.
35
A/D
36
OUTPUT/ DISPLAY
38
I/O
37
I/O
37'
EROM
46
RAM
45
ASIC
44
LEDS
22
ILLUM. OPTICS
24
20
IMAGING OPTICS
34
30
D
T
MICRO PROCESSOR
42
40
42A
42B
I/O
37"
OUTPUT/ DISPLAY
38'
48

FIG.1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32–2
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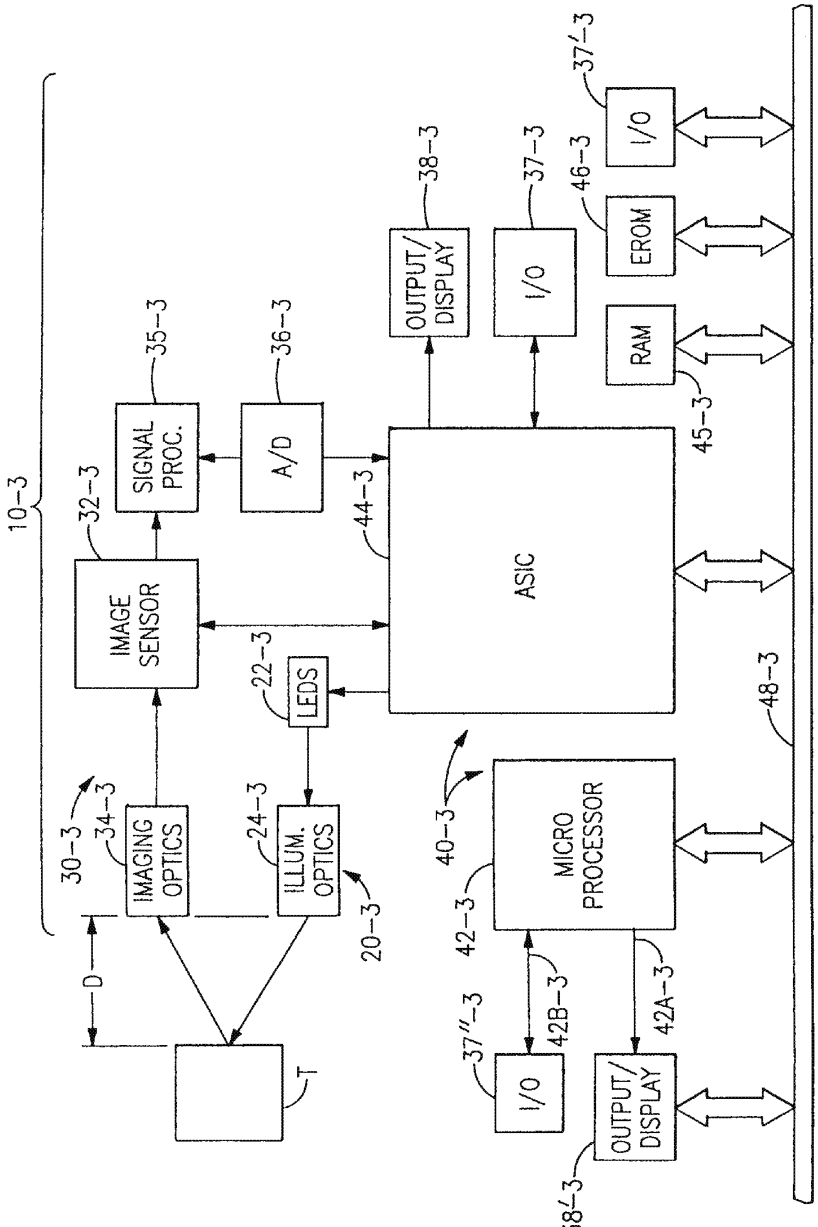
A/D
36–2
OUTPUT/ DISPLAY
38–2
I/O
37–2
EROM
46–2
I/O
37'–2
RAM
45–2
ASIC
44–2
LEDS
22–2
IMAGING OPTICS
34–2
30–2
ILLUM. OPTICS
24–2
20–2
D
T
MICRO PROCESSOR
40–2
42–2
48–2
I/O
37''–2
42B–2
OUTPUT/ DISPLAY
42A–2
38'–2

FIG.2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37–3
RAM
45–3
EROM
46–3
I/O
37′–3
LEDS
22–3
IMAGING OPTICS
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ILLUM. OPTICS
24–3
20–3
D
T
MICRO PROCESSOR
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I/O
37″–3
42B–3
OUTPUT/ DISPLAY
42A–3
38′–3
48–3

FIG.3

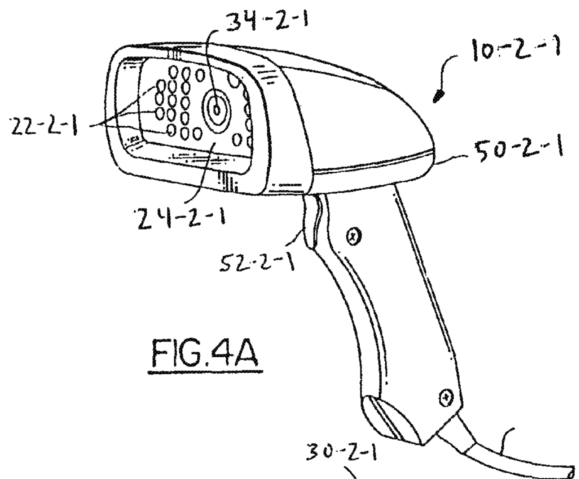


FIG.4A

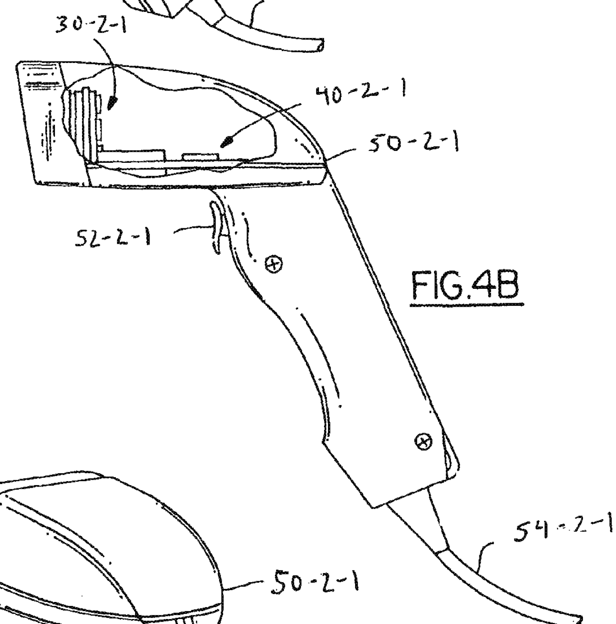


FIG.4B

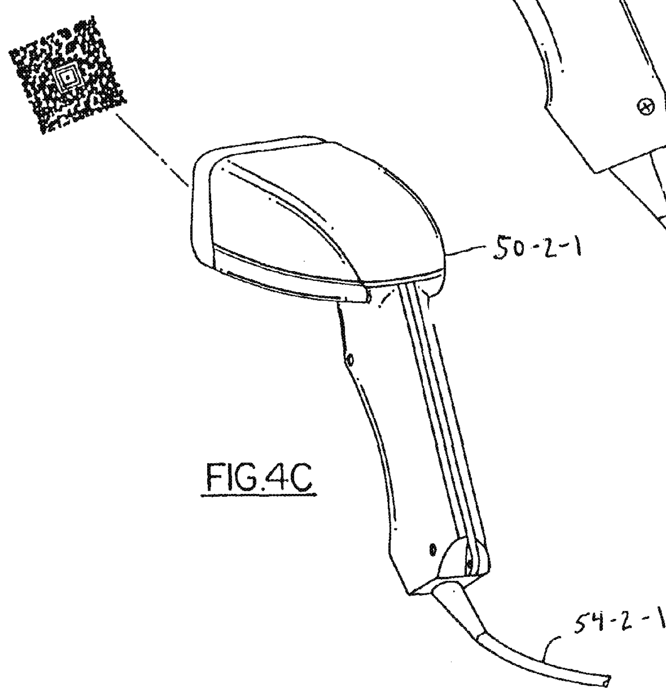


FIG.4C

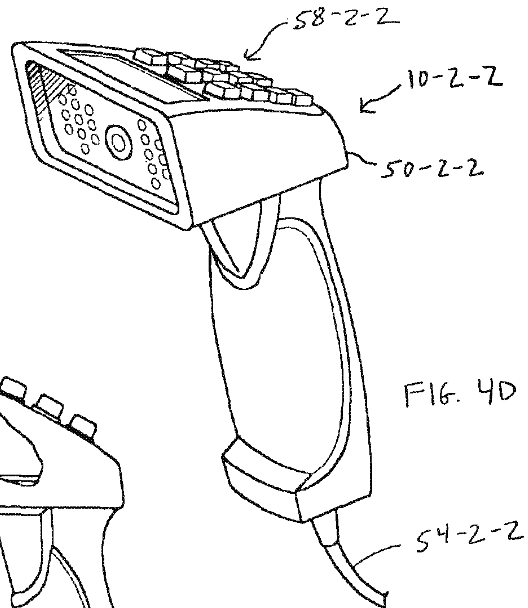


FIG. 4D

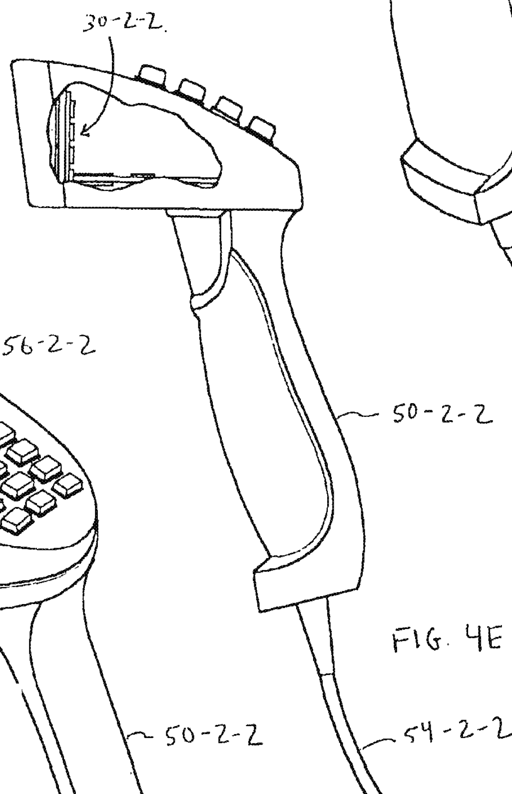


FIG. 4E

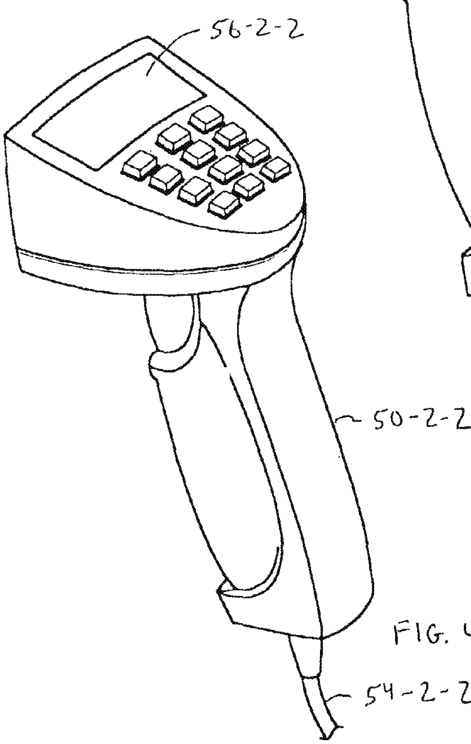


FIG. 4F

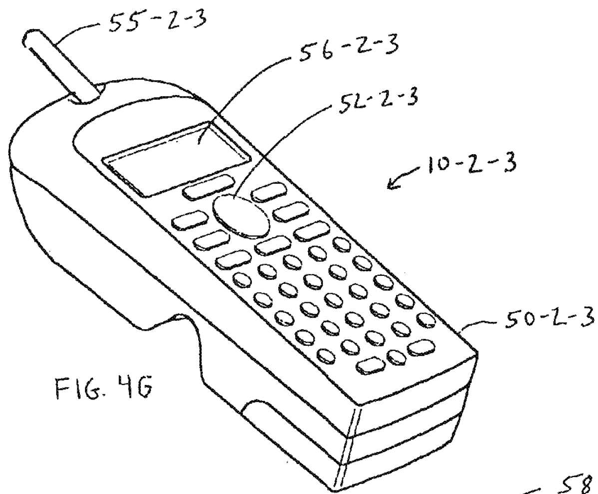


FIG. 4G

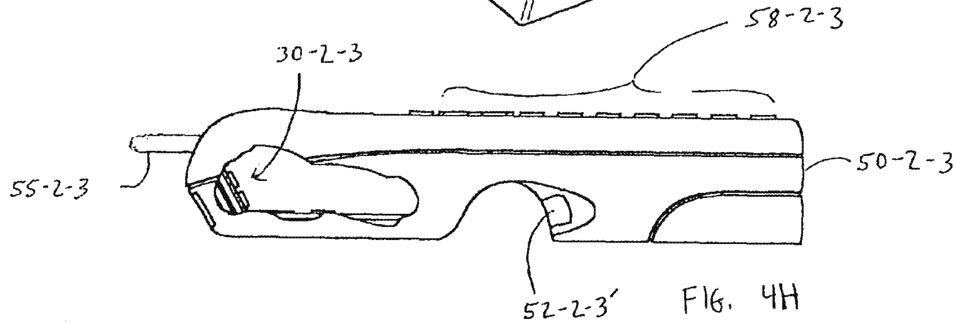


FIG. 4H

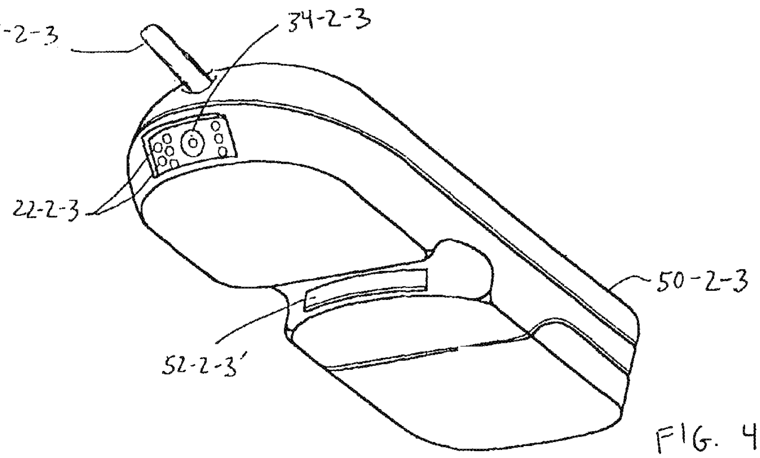


FIG. 4I

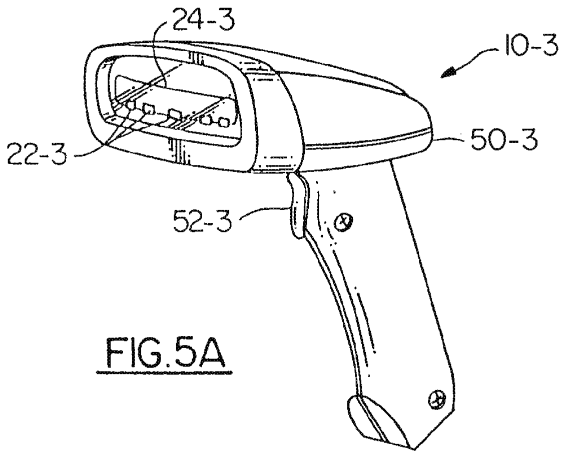


FIG.5A

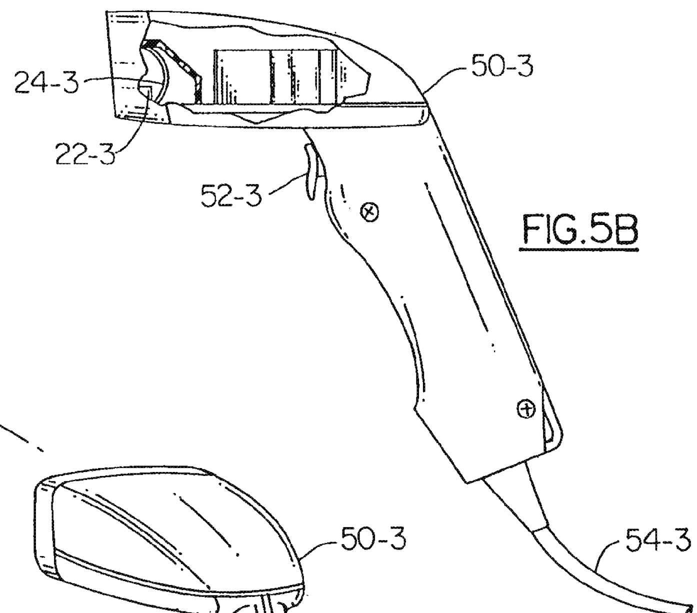


FIG.5B

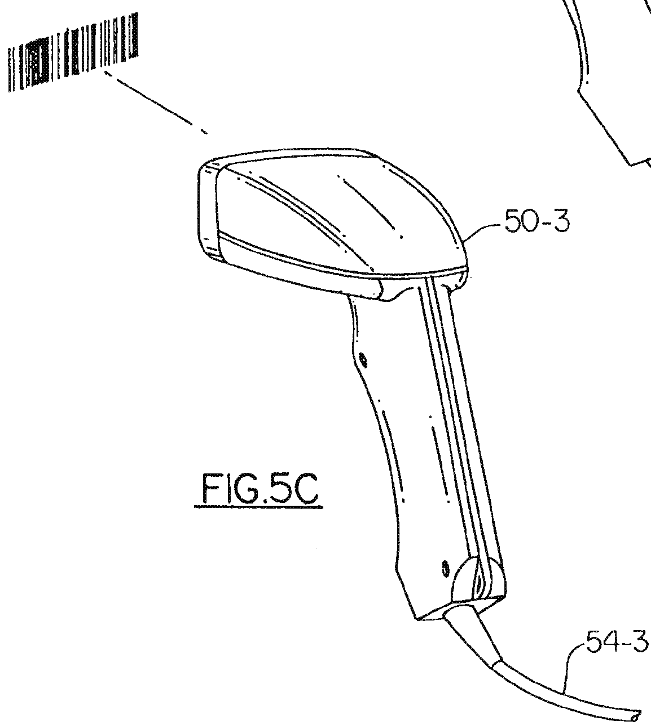


FIG.5C

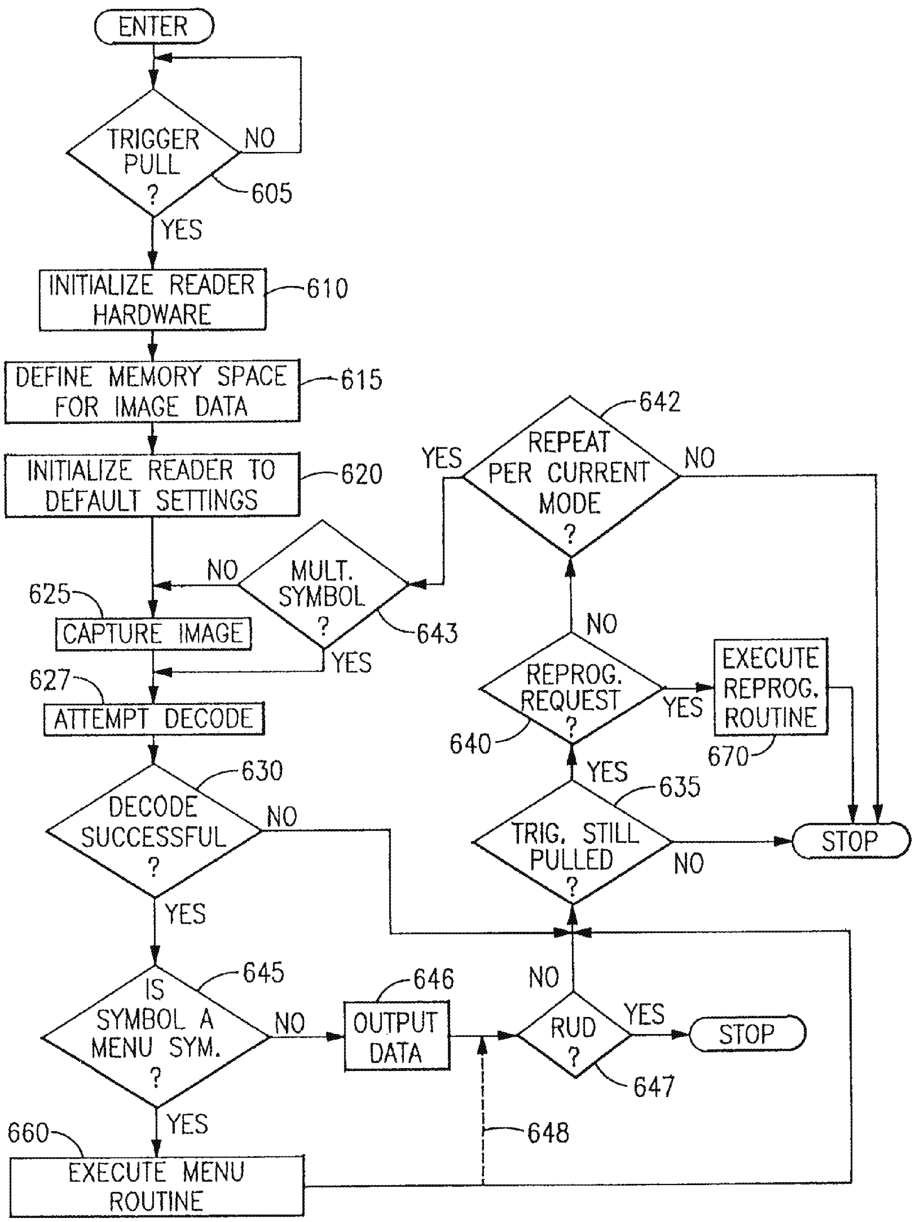

ENTER
TRIGGER PULL ?
NO
605
YES
INITIALIZE READER HARDWARE
610
DEFINE MEMORY SPACE FOR IMAGE DATA
615
INITIALIZE READER TO DEFAULT SETTINGS
620
625
CAPTURE IMAGE
NO
MULT. SYMBOL ?
643
YES
627
ATTEMPT DECODE
DECODE SUCCESSFUL ?
630
NO
YES
IS SYMBOL A MENU SYM. ?
645
NO
OUTPUT DATA
646
RUD ?
647
NO
YES
STOP
648
YES
660
EXECUTE MENU ROUTINE
642
REPEAT PER CURRENT MODE ?
YES
NO
NO
REPROG. REQUEST ?
640
YES
EXECUTE REPROG. ROUTINE
670
YES
635
TRIG. STILL PULLED ?
NO
STOP

FIG. 6A

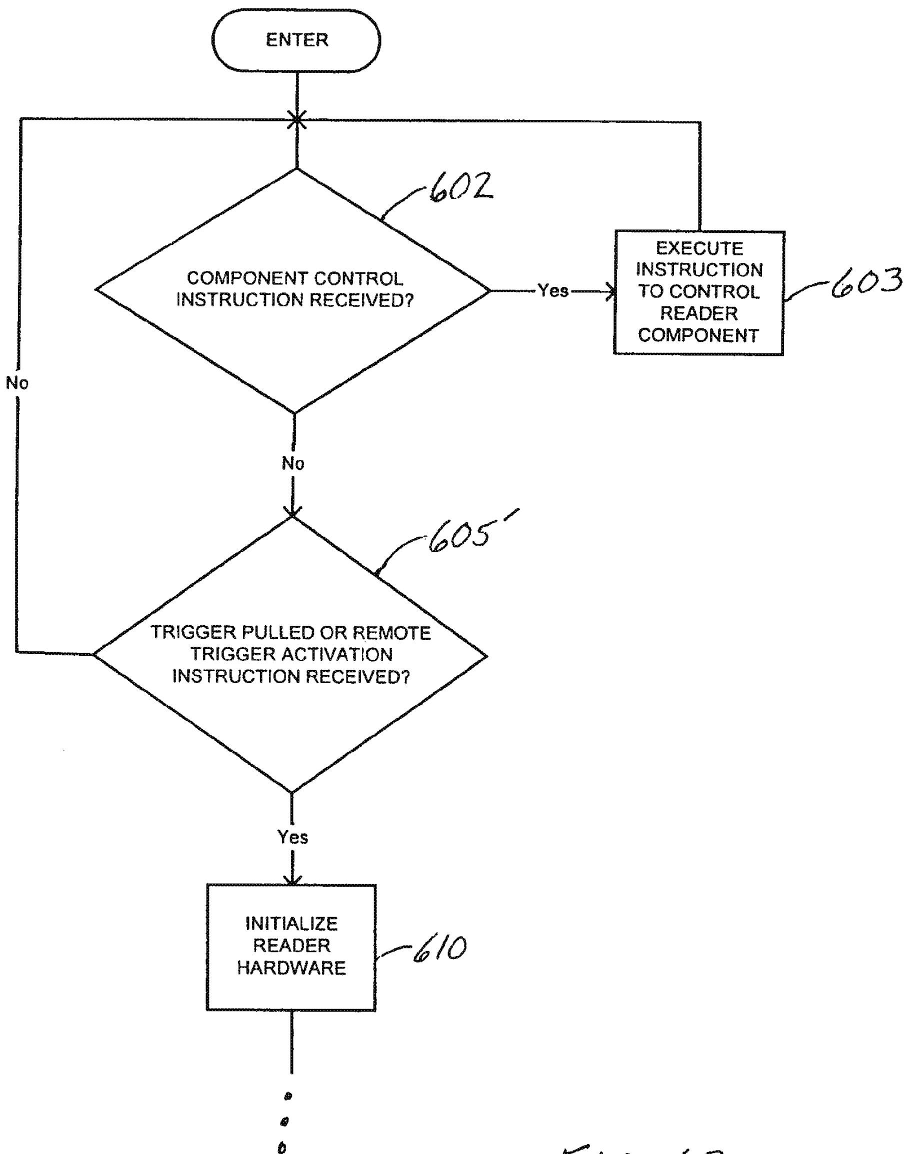

ENTER
602
COMPONENT CONTROL INSTRUCTION RECEIVED?
Yes
EXECUTE INSTRUCTION TO CONTROL READER COMPONENT
603
No
No
605
TRIGGER PULLED OR REMOTE TRIGGER ACTIVATION INSTRUCTION RECEIVED?
Yes
INITIALIZE READER HARDWARE
610

FIG. 6B

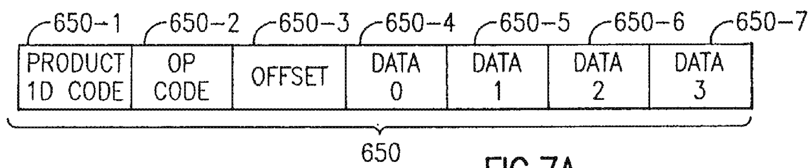


FIG.7A

OPTIONS (OFFSET) TABLE

A. COMMUNICATIONS OPTIONS
   1. RS-232
   2. BAUD RATE
   3. RF LINK
   4. ETHERNET
B. CODE OPTIONS
   1. DISABLE 1D
   2. DISABLE 2D
   3. DISABLE INDIV.
   4. MIN-MAX LENGTH
   5. MULTIPLE SYMBOLS ENABLED
C. SCANNING-DECODING OPTIONS
   1. ONE SHOT
   2. REPEAT UNTIL DONE
   3. REPEAT UNTIL STOPPED
   4. SCAN ON DEMAND
   5. SKIP SCAN
   6. DECODE ON DEMAND
D. OPERATING OPTIONS
   1. BEEPER VOLUME
   2. AIMING LED ON/OFF
   3. AURAL FEEDBACK
E. TRANSMIT OPTIONS
   1. SEND CHECK CHAR'S
   2. SEND CHECKSUM
   3. DATA EDIT OPTIONS

FIG.7B

OP CODE TABLE

A. OP CODE "0"-VECTOR PROC.
   1. OUTPUT VERSION OF SOFTWARE
   2. OUTPUT CONTENTS OF PARAMETER TABLE
   3. DISPLAY ENABLED CODES
   4. PRINT PARAMETER TABLE AS BAR CODE SYMBOL
B. OP CODE "1" - CLEAR
C. OP CODE "2" - SET
D. OP CODE "3" - TOGGLE
E. OP CODE "4" - ADD
F. OP CODE "5" - DEFAULT
G. OP CODE "6" - LOAD
H. OP CODE "7" - RESERVED

FIG.7C

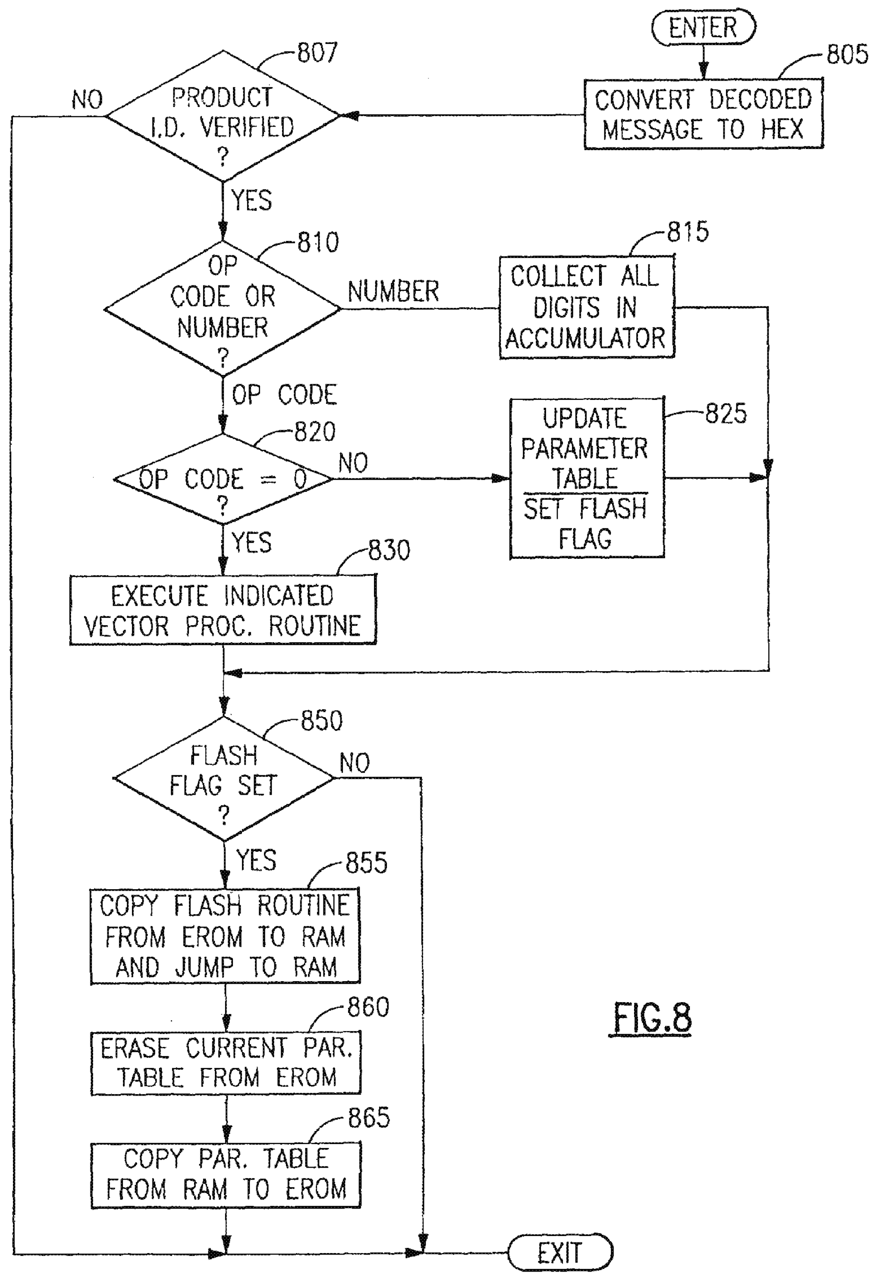

ENTER
805
CONVERT DECODED MESSAGE TO HEX
807
PRODUCT I.D. VERIFIED ?
NO
YES
810
OP CODE OR NUMBER ?
NUMBER
815
COLLECT ALL DIGITS IN ACCUMULATOR
OP CODE
820
OP CODE = 0 ?
NO
825
UPDATE PARAMETER TABLE
SET FLASH FLAG
YES
830
EXECUTE INDICATED VECTOR PROC. ROUTINE
850
FLASH FLAG SET ?
NO
YES
855
COPY FLASH ROUTINE FROM EROM TO RAM AND JUMP TO RAM
860
ERASE CURRENT PAR. TABLE FROM EROM
865
COPY PAR. TABLE FROM RAM TO EROM
EXIT

FIG.8

FIG.8A

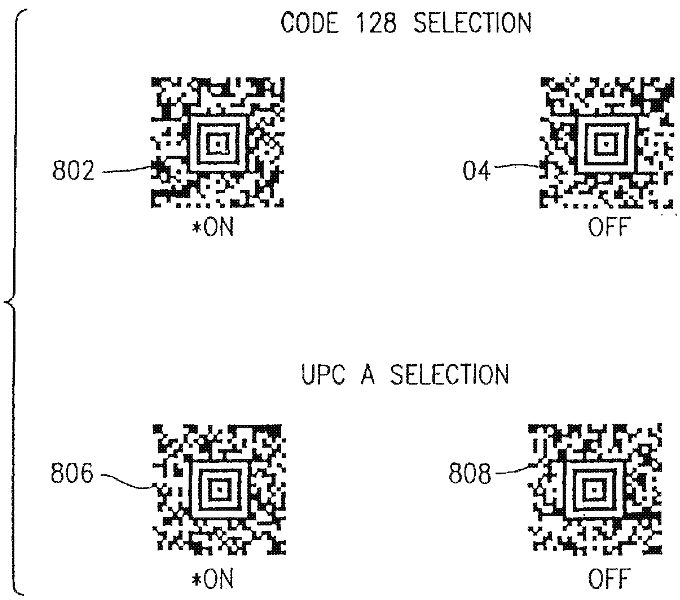

CODE 128 SELECTION
802
*ON
04
OFF
UPC A SELECTION
806
*ON
808
OFF

FIG.8B

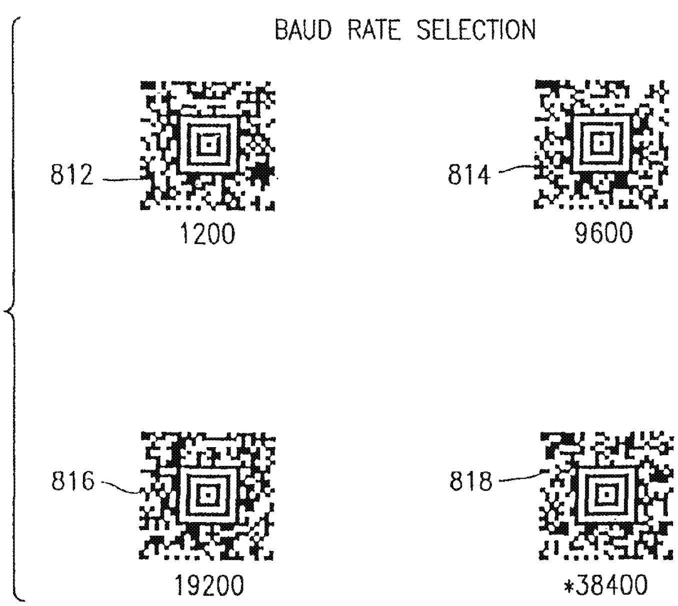

BAUD RATE SELECTION
812
1200
814
9600
816
19200
818
*38400

FIG.8C

DEFAULT ALL CODE 11/CODE 128 SETTINGS

822

CODE 11 SELECTION

824

*ON

CODE 11

826

OFF

828

*2 CHECK DIGITS

CHECK DIGITS REQUIRED

832

1 CHECK DIGIT

834

MINIMUM ‡

MESSAGE LENGTH

836

MAXIMUM ‡

CODE 128 SELECTION

848

*ON

CODE 128

852

OFF

854

MINIMUM ‡

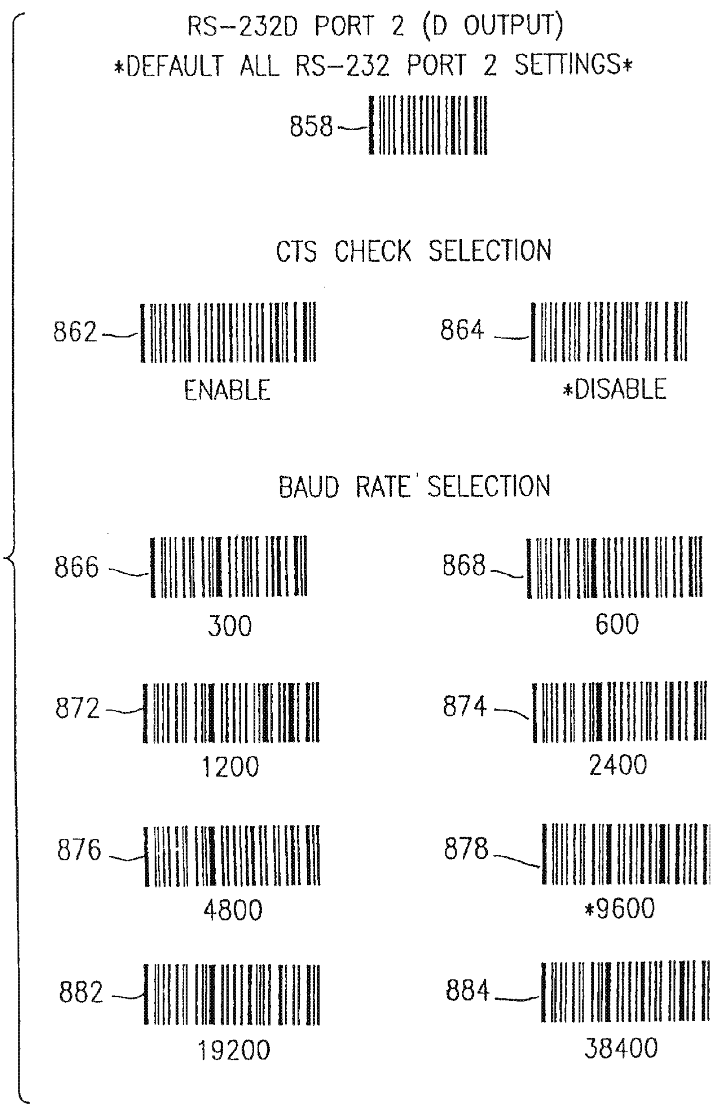
MESSAGE LENGTH

856

MAXIMUM ‡

‡ A TWO-DIGIT NUMBER IS REQUIRED AFTER SCANNING THIS PROGRAMMING BAR CODE. PLEASE SCAN YOUR SELECTION ON THE PROGRAMMING CHART (INSIDE BACK COVER).

FIG.8D


RS-232D PORT 2 (D OUTPUT)
DEFAULT ALL RS-232 PORT 2 SETTINGS
858
CTS CHECK SELECTION
862
ENABLE
864
*DISABLE
BAUD RATE SELECTION
866
300
868
600
872
1200
874
2400
876
4800
878
*9600
882
19200
884
38400

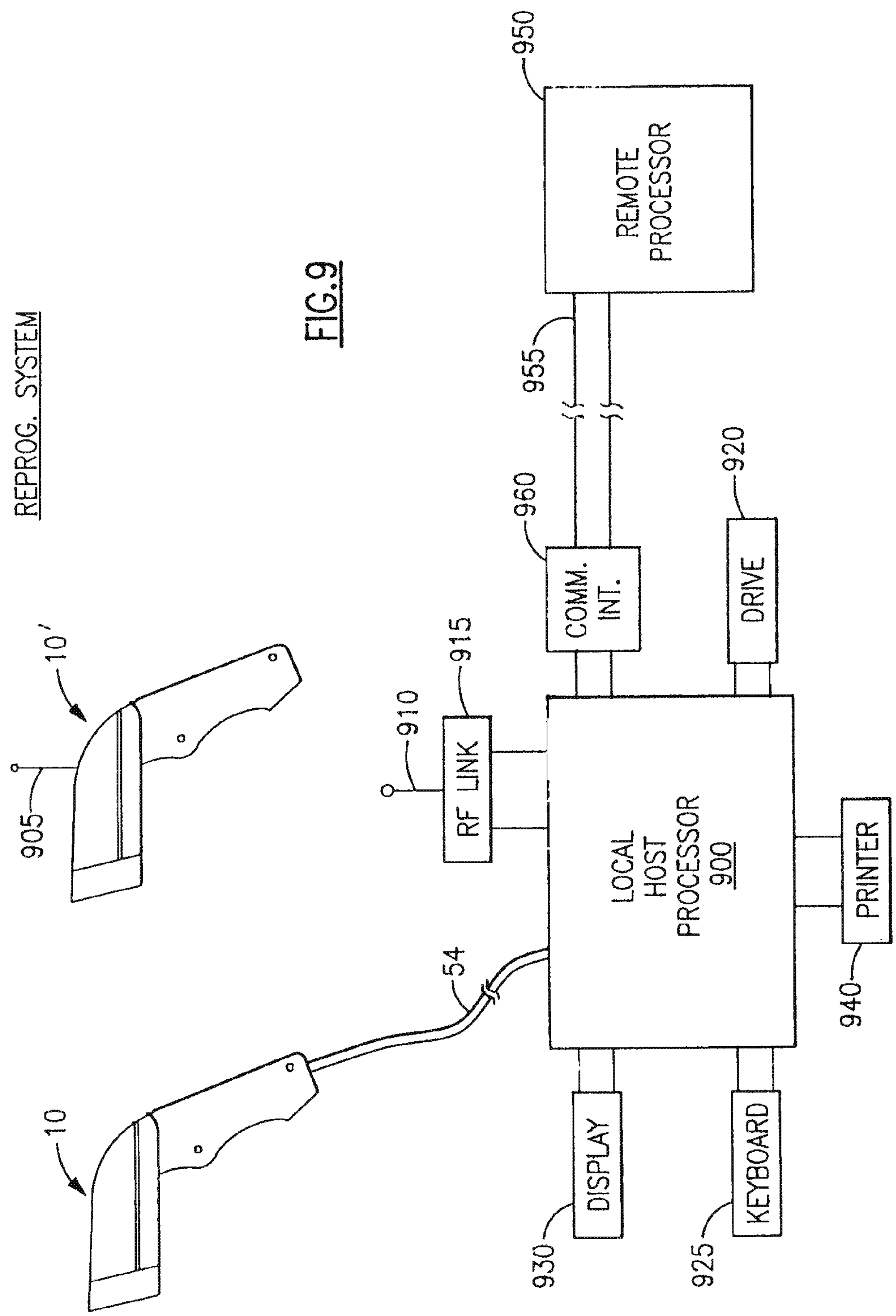

REPROG. SYSTEM
REMOTE PROCESSOR
950
955
960
COMM. INT.
920
DRIVE
915
RF LINK
910
LOCAL HOST PROCESSOR 900
PRINTER
940
54
DISPLAY
930
KEYBOARD
925
10′
905
10

FIG.9

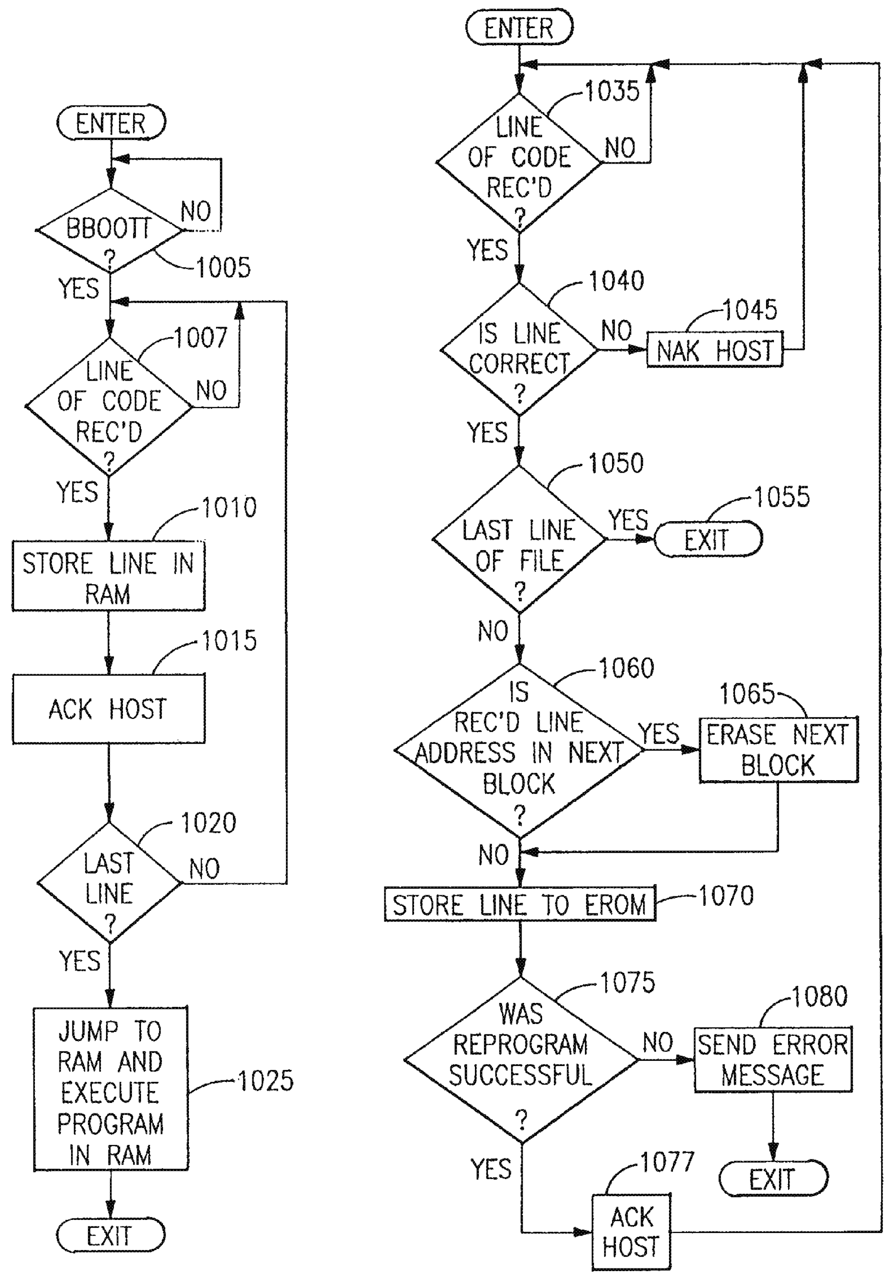


FIG. 10A

FIG. 10B

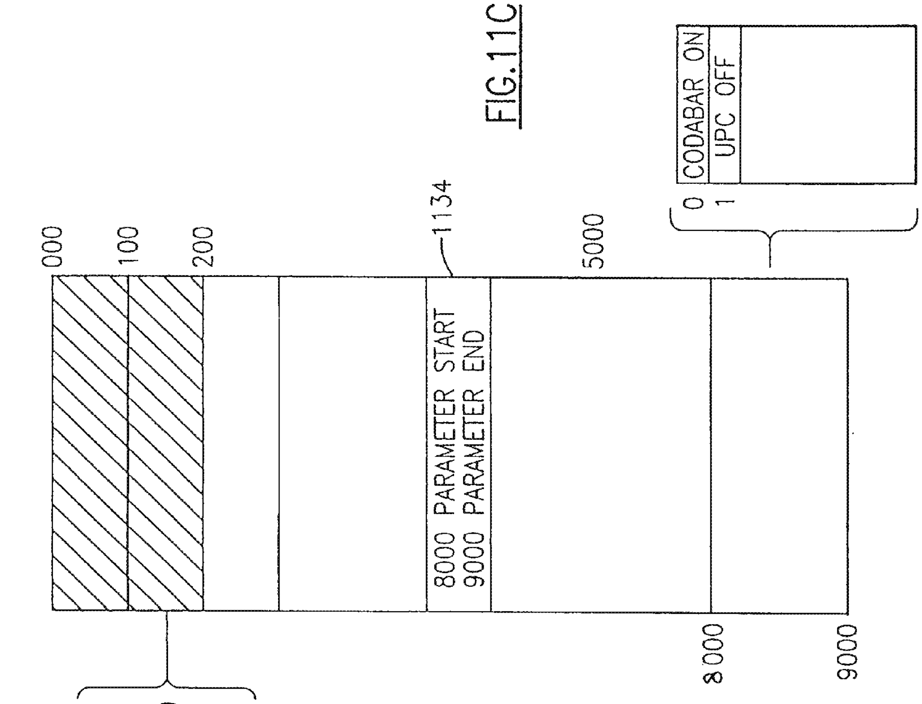


FIG.11C

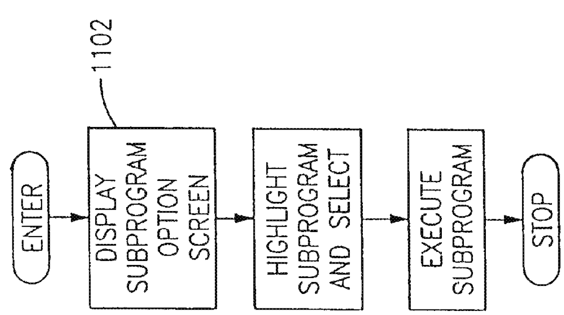


FIG.11A

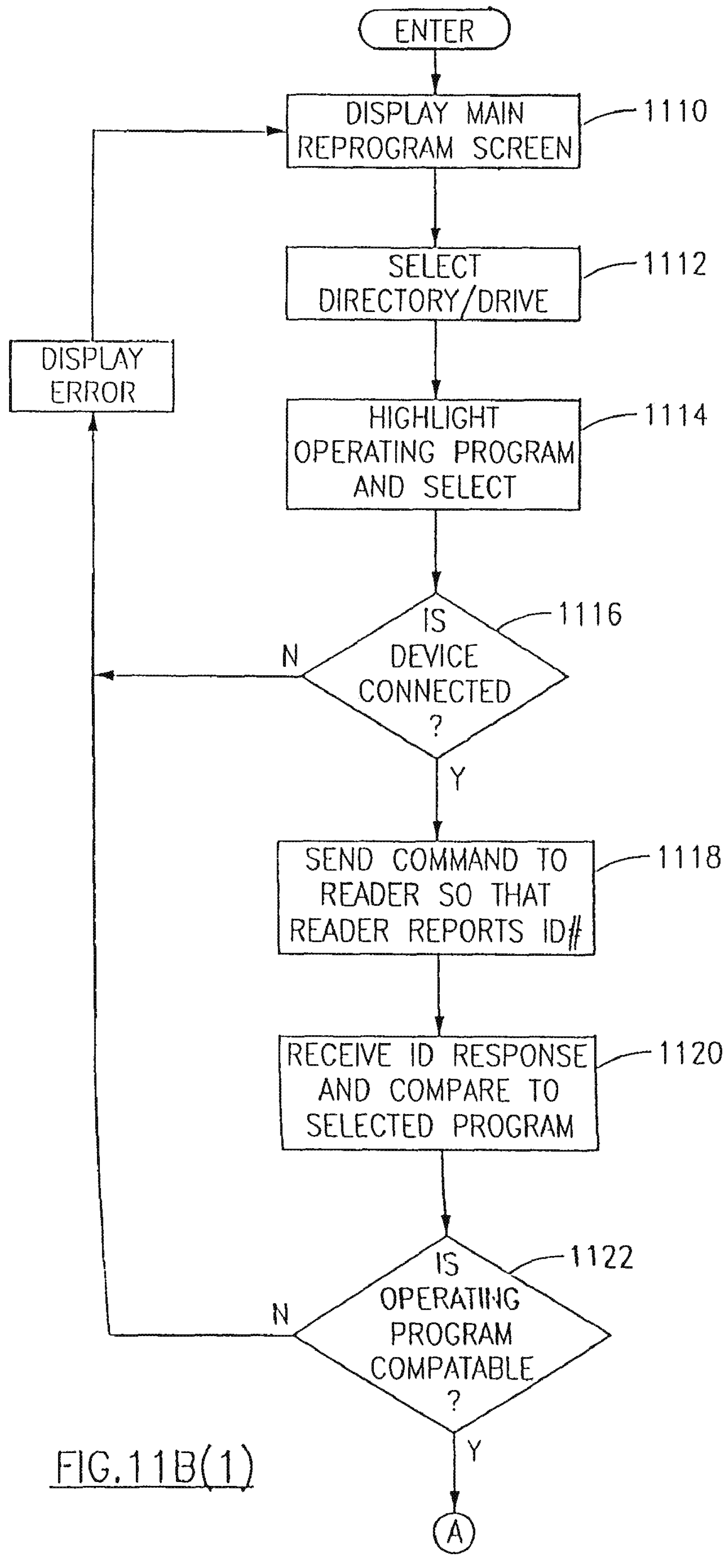


FIG.11B(1)

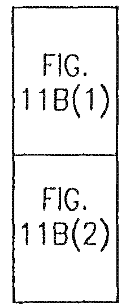
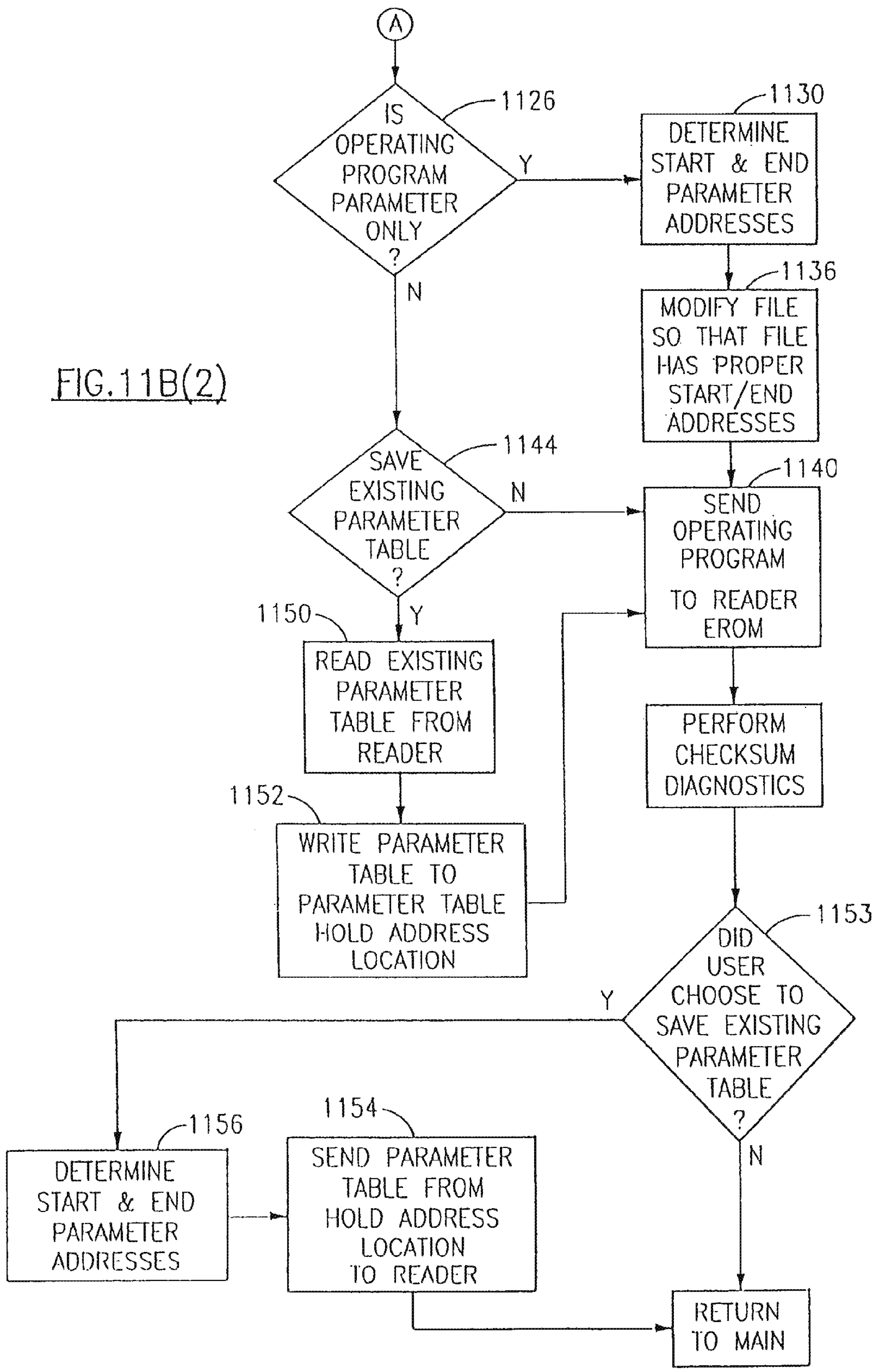


FIG.11B

FIG.11B(2)


A
IS OPERATING PROGRAM PARAMETER ONLY ?
1126
Y
N
DETERMINE START & END PARAMETER ADDRESSES
1130
MODIFY FILE SO THAT FILE HAS PROPER START/END ADDRESSES
1136
SAVE EXISTING PARAMETER TABLE ?
1144
N
Y
SEND OPERATING PROGRAM TO READER EROM
1140
1150
READ EXISTING PARAMETER TABLE FROM READER
1152
WRITE PARAMETER TABLE TO PARAMETER TABLE HOLD ADDRESS LOCATION
PERFORM CHECKSUM DIAGNOSTICS
DID USER CHOOSE TO SAVE EXISTING PARAMETER TABLE ?
1153
Y
N
1156
DETERMINE START & END PARAMETER ADDRESSES
1154
SEND PARAMETER TABLE FROM HOLD ADDRESS LOCATION TO READER
RETURN TO MAIN

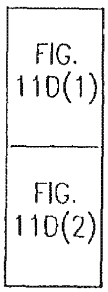


FIG.11D

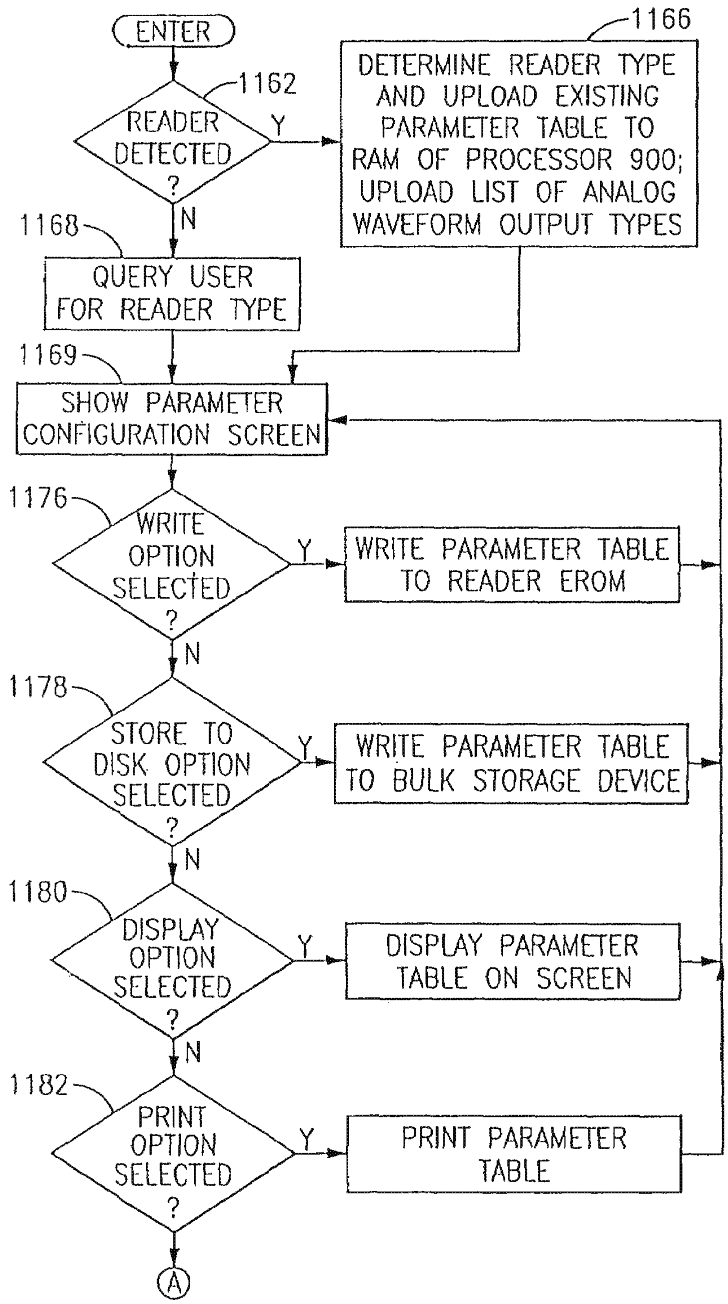


FIG.11D(1)

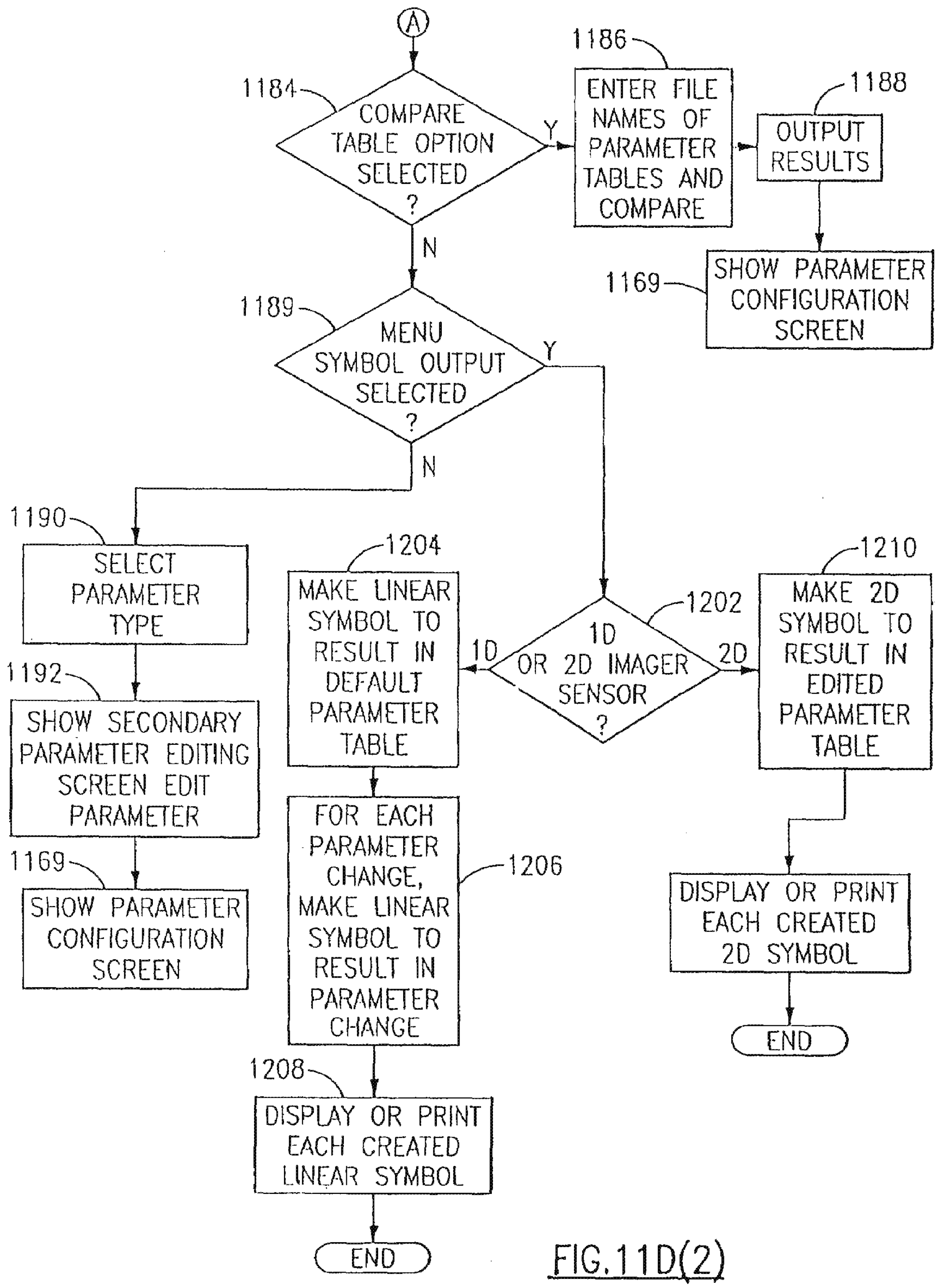

A
1184
COMPARE TABLE OPTION SELECTED ?
Y
N
1186
ENTER FILE NAMES OF PARAMETER TABLES AND COMPARE
1188
OUTPUT RESULTS
1169
SHOW PARAMETER CONFIGURATION SCREEN
1189
MENU SYMBOL OUTPUT SELECTED ?
Y
N
1190
SELECT PARAMETER TYPE
1192
SHOW SECONDARY PARAMETER EDITING SCREEN EDIT PARAMETER
1169
SHOW PARAMETER CONFIGURATION SCREEN
1204
MAKE LINEAR SYMBOL TO RESULT IN DEFAULT PARAMETER TABLE
1206
FOR EACH PARAMETER CHANGE, MAKE LINEAR SYMBOL TO RESULT IN PARAMETER CHANGE
1208
DISPLAY OR PRINT EACH CREATED LINEAR SYMBOL
END
1202
1D OR 2D IMAGER SENSOR ?
1D
2D
1210
MAKE 2D SYMBOL TO RESULT IN EDITED PARAMETER TABLE
DISPLAY OR PRINT EACH CREATED 2D SYMBOL
END

FIG.11D(2)

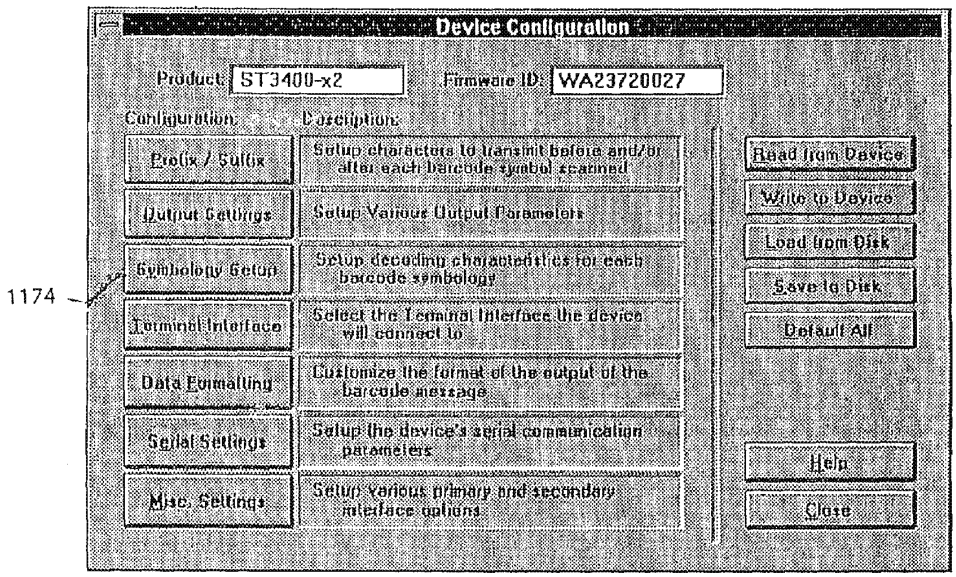

Device Configuration
Product: ST3400-x2
Firmware ID: WA23720027
Configuration:
Description:
Prefix / Suffix
Setup characters to transmit before and/or after each barcode symbol scanned
Output Settings
Setup Various Output Parameters
Symbology Setup
Setup decoding characteristics for each barcode symbology
Terminal Interface
Select the Terminal Interface the device will connect to
Data Formatting
Customize the format of the output of the barcode message
Serial Settings
Setup the device's serial communication parameters
Misc. Settings
Setup various primary and secondary interface options
Read from Device
Write to Device
Load from Disk
Save to Disk
Default All
Help
Close
1174

FIG. 11E

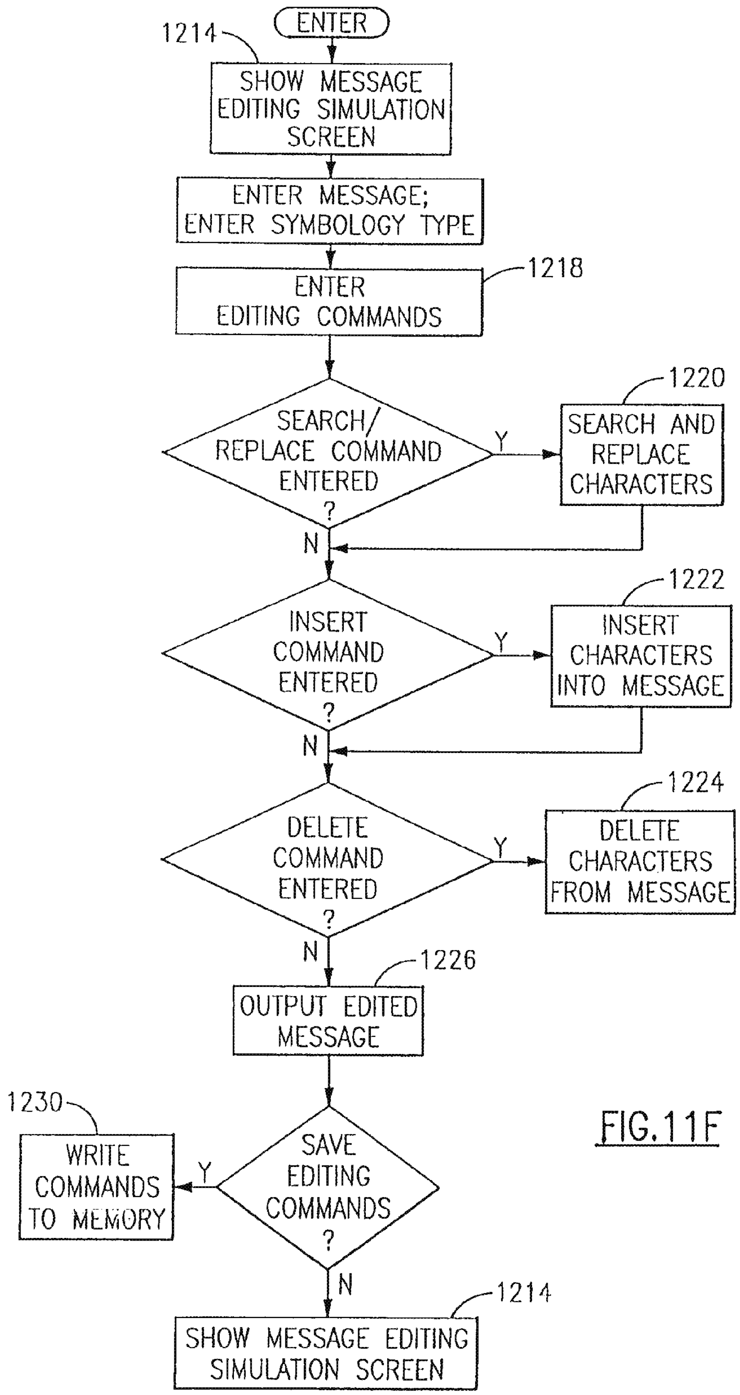

ENTER
1214
SHOW MESSAGE EDITING SIMULATION SCREEN
ENTER MESSAGE; ENTER SYMBOLOGY TYPE
1218
ENTER EDITING COMMANDS
SEARCH/ REPLACE COMMAND ENTERED ?
Y
N
1220
SEARCH AND REPLACE CHARACTERS
INSERT COMMAND ENTERED ?
Y
N
1222
INSERT CHARACTERS INTO MESSAGE
DELETE COMMAND ENTERED ?
Y
N
1224
DELETE CHARACTERS FROM MESSAGE
1226
OUTPUT EDITED MESSAGE
SAVE EDITING COMMANDS ?
Y
N
1230
WRITE COMMANDS TO MEMORY
1214
SHOW MESSAGE EDITING SIMULATION SCREEN

FIG.11F

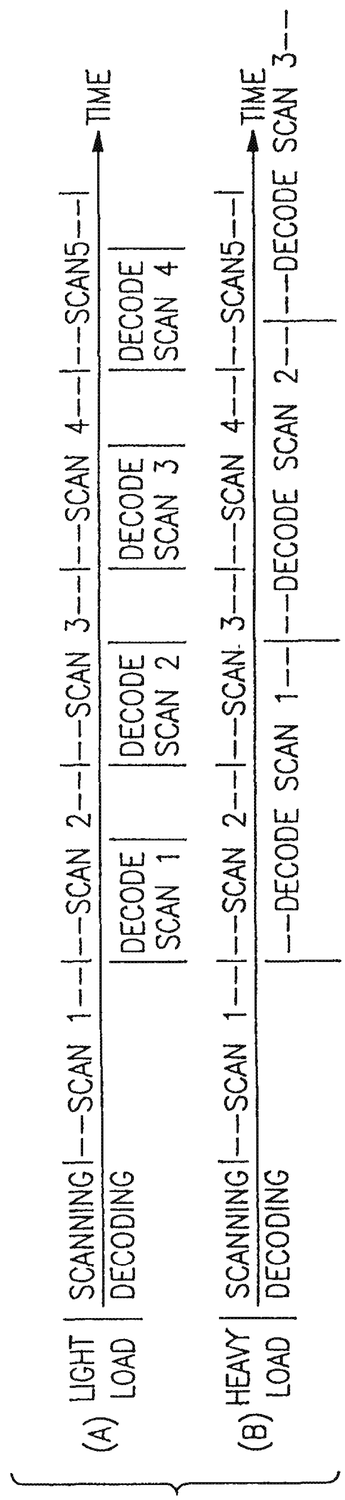


FIG.12
Prior Art

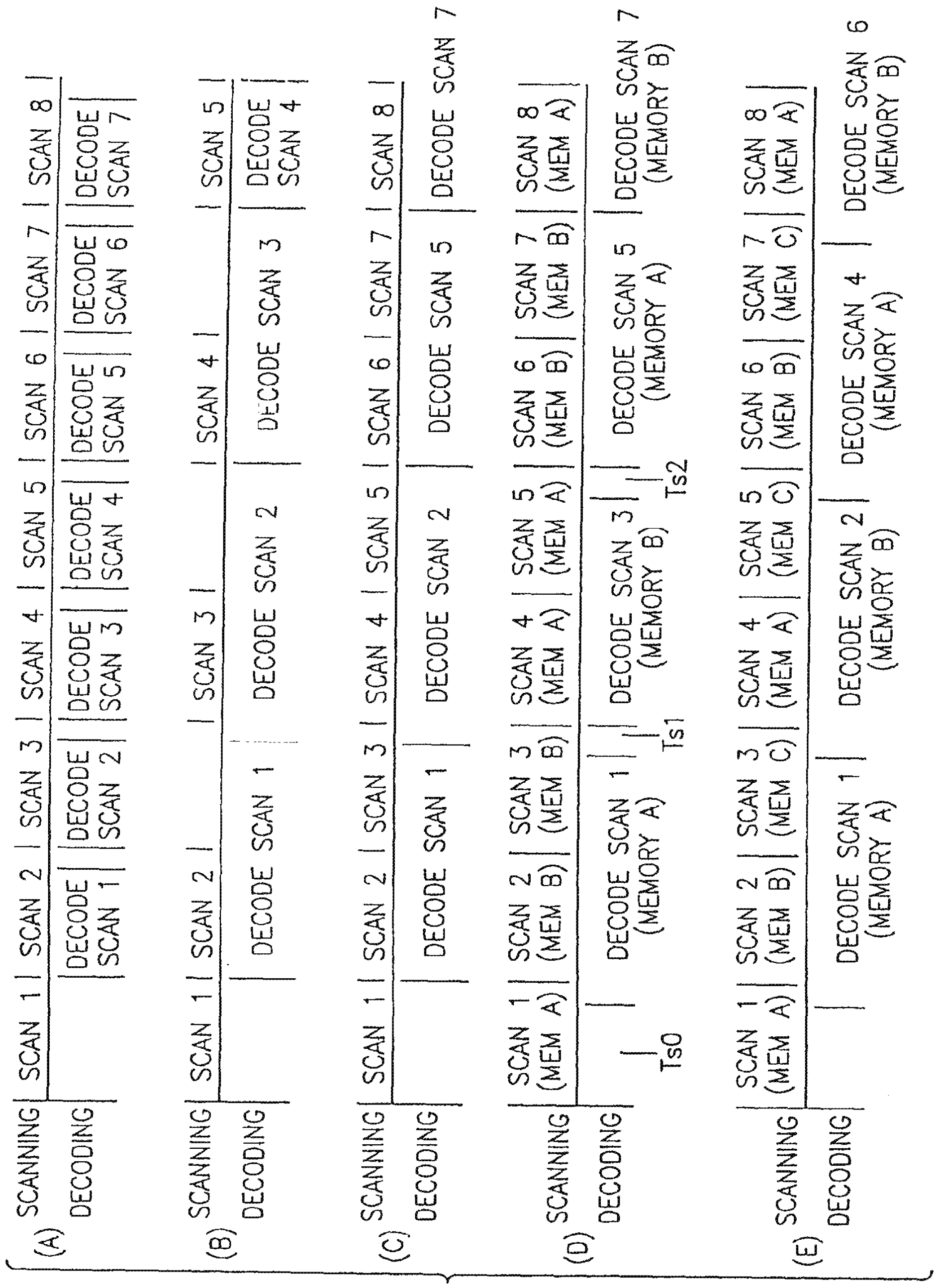
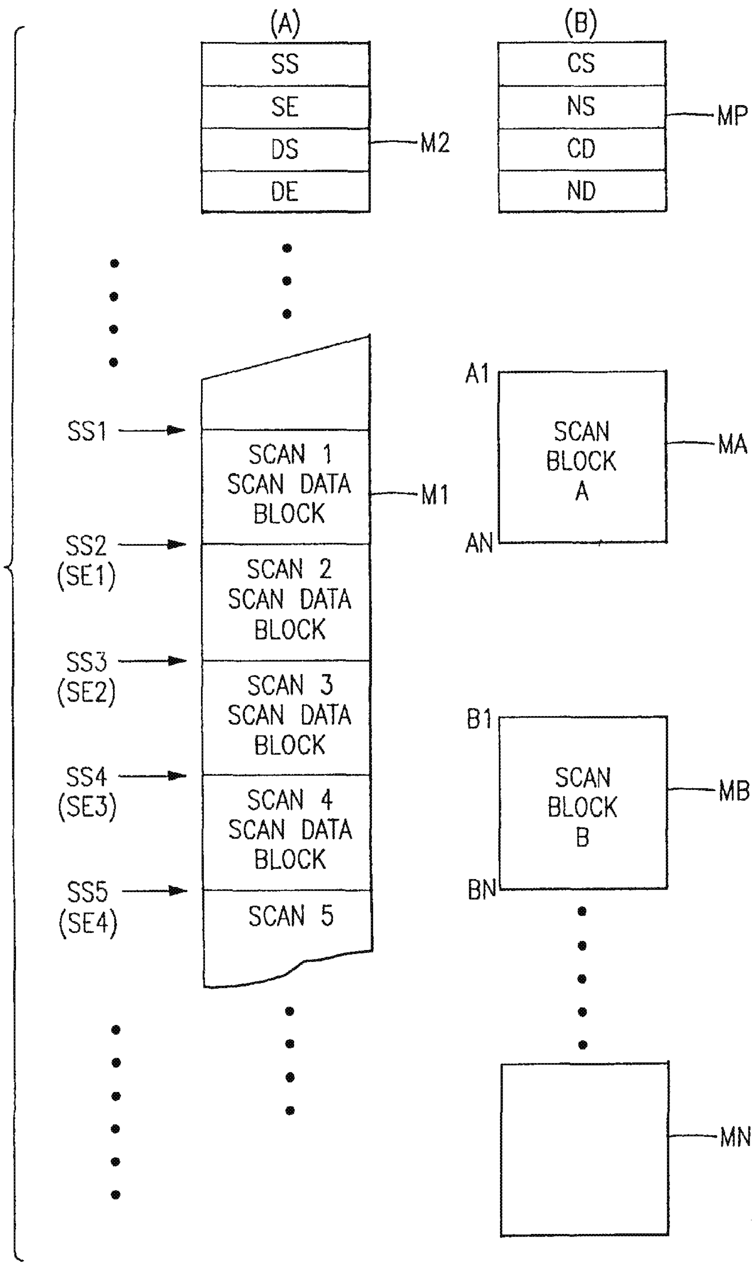

(A)
SCANNING
SCAN 1
SCAN 2
SCAN 3
SCAN 4
SCAN 5
SCAN 6
SCAN 7
SCAN 8
DECODING
DECODE SCAN 1
DECODE SCAN 2
DECODE SCAN 3
DECODE SCAN 4
DECODE SCAN 5
DECODE SCAN 6
DECODE SCAN 7
(B)
SCANNING
SCAN 1
SCAN 2
SCAN 3
SCAN 4
SCAN 5
DECODING
DECODE SCAN 1
DECODE SCAN 2
DECODE SCAN 3
DECODE SCAN 4
(C)
SCANNING
SCAN 1
SCAN 2
SCAN 3
SCAN 4
SCAN 5
SCAN 6
SCAN 7
SCAN 8
DECODING
DECODE SCAN 1
DECODE SCAN 2
DECODE SCAN 5
DECODE SCAN 7
(D)
SCANNING
SCAN 1 (MEM A)
SCAN 2 (MEM B)
SCAN 3 (MEM B)
SCAN 4 (MEM A)
SCAN 5 (MEM A)
SCAN 6 (MEM B)
SCAN 7 (MEM B)
SCAN 8 (MEM A)
DECODING
Ts0
DECODE SCAN 1 (MEMORY A)
Ts1
DECODE SCAN 3 (MEMORY B)
Ts2
DECODE SCAN 5 (MEMORY A)
DECODE SCAN 7 (MEMORY B)
(E)
SCANNING
SCAN 1 (MEM A)
SCAN 2 (MEM B)
SCAN 3 (MEM C)
SCAN 4 (MEM A)
SCAN 5 (MEM C)
SCAN 6 (MEM B)
SCAN 7 (MEM C)
SCAN 8 (MEM A)
DECODING
DECODE SCAN 1 (MEMORY A)
DECODE SCAN 2 (MEMORY B)
DECODE SCAN 4 (MEMORY A)
DECODE SCAN 6 (MEMORY B)

FIG.13

FIG.14


(A)
SS
SE
DS
DE
M2
(B)
CS
NS
CD
ND
MP
SS1
SCAN 1 SCAN DATA BLOCK
M1
SS2 (SE1)
SCAN 2 SCAN DATA BLOCK
SS3 (SE2)
SCAN 3 SCAN DATA BLOCK
SS4 (SE3)
SCAN 4 SCAN DATA BLOCK
SS5 (SE4)
SCAN 5
A1
SCAN BLOCK A
AN
MA
B1
SCAN BLOCK B
BN
MB
MN

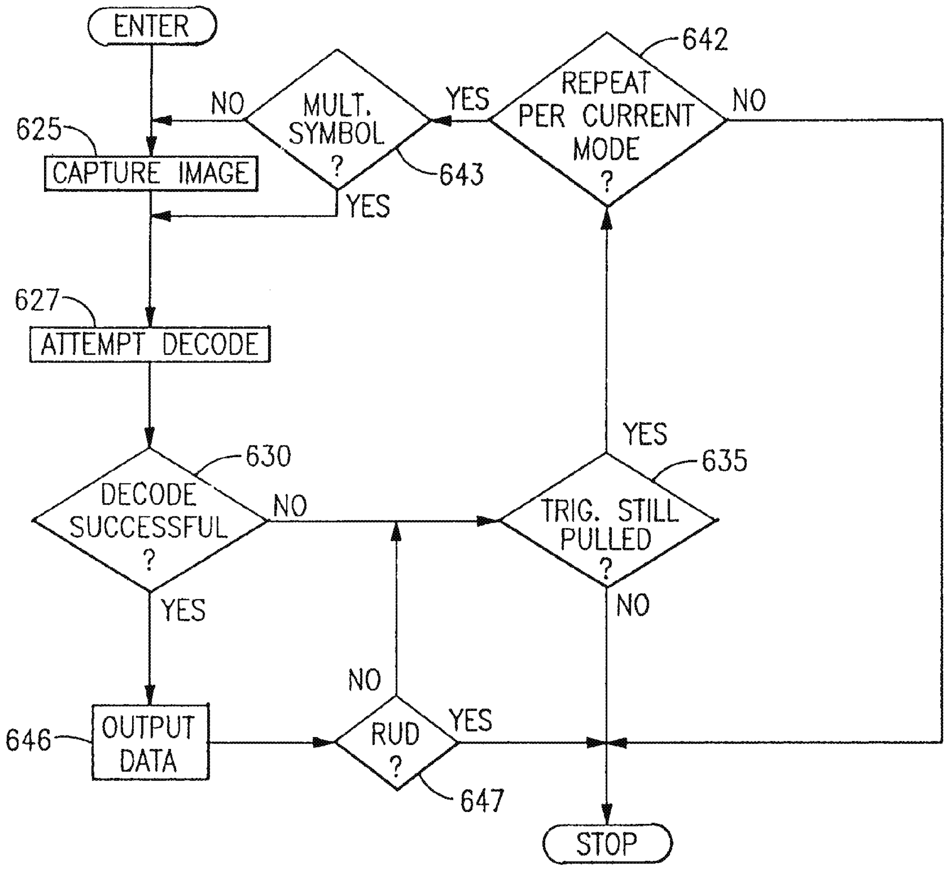

ENTER
625
CAPTURE IMAGE
NO
MULT. SYMBOL ?
643
YES
YES
REPEAT PER CURRENT MODE ?
642
NO
627
ATTEMPT DECODE
630
DECODE SUCCESSFUL ?
NO
YES
635
TRIG. STILL PULLED ?
YES
NO
646
OUTPUT DATA
NO
RUD ?
YES
647
STOP

FIG.15

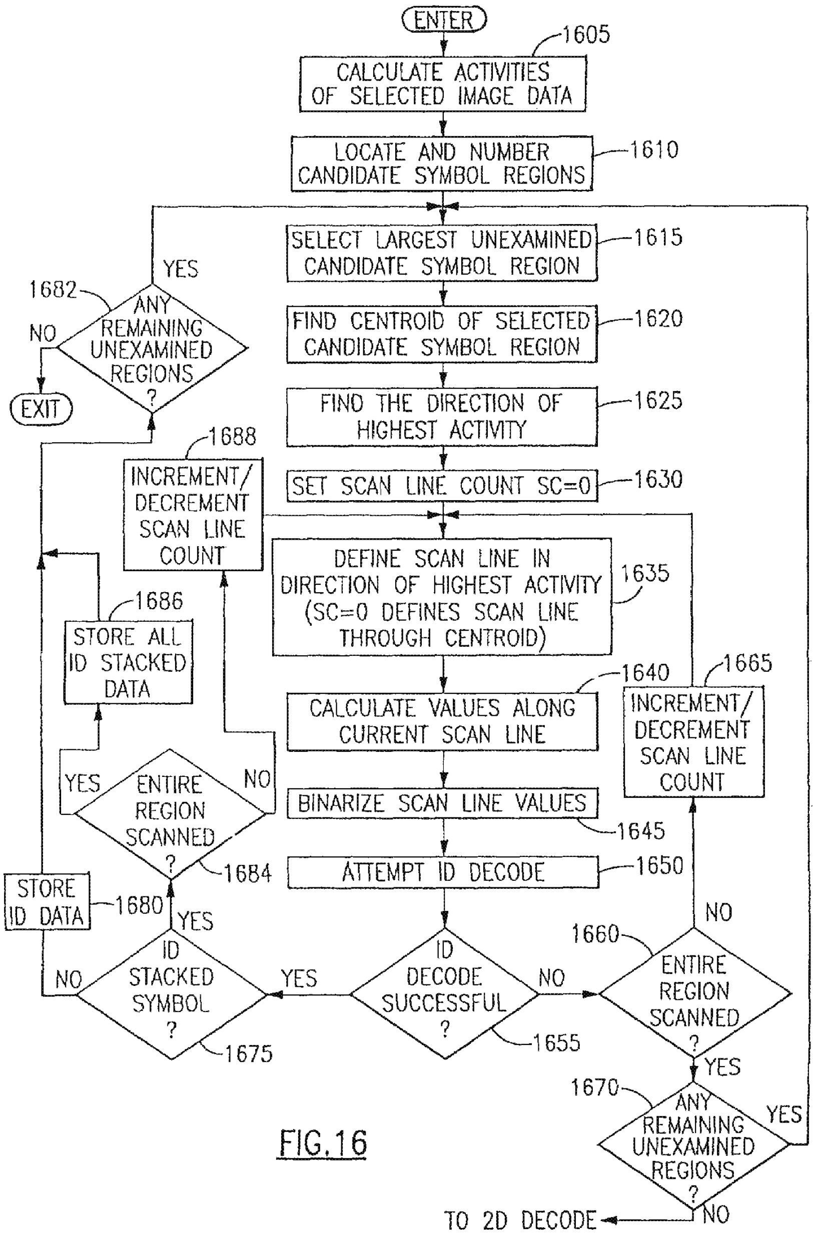

ENTER
1605
CALCULATE ACTIVITIES OF SELECTED IMAGE DATA
LOCATE AND NUMBER CANDIDATE SYMBOL REGIONS
1610
SELECT LARGEST UNEXAMINED CANDIDATE SYMBOL REGION
1615
FIND CENTROID OF SELECTED CANDIDATE SYMBOL REGION
1620
FIND THE DIRECTION OF HIGHEST ACTIVITY
1625
SET SCAN LINE COUNT SC=0
1630
DEFINE SCAN LINE IN DIRECTION OF HIGHEST ACTIVITY (SC=0 DEFINES SCAN LINE THROUGH CENTROID)
1635
CALCULATE VALUES ALONG CURRENT SCAN LINE
1640
BINARIZE SCAN LINE VALUES
1645
ATTEMPT ID DECODE
1650
ID DECODE SUCCESSFUL ?
1655
YES
NO
ENTIRE REGION SCANNED ?
1660
NO
YES
INCREMENT/ DECREMENT SCAN LINE COUNT
1665
ANY REMAINING UNEXAMINED REGIONS ?
1670
YES
NO
TO 2D DECODE
ID STACKED SYMBOL ?
1675
YES
NO
STORE ID DATA
1680
ENTIRE REGION SCANNED ?
1684
YES
NO
STORE ALL ID STACKED DATA
1686
INCREMENT/ DECREMENT SCAN LINE COUNT
1688
ANY REMAINING UNEXAMINED REGIONS ?
1682
YES
NO
EXIT

FIG. 16

FIG.17A

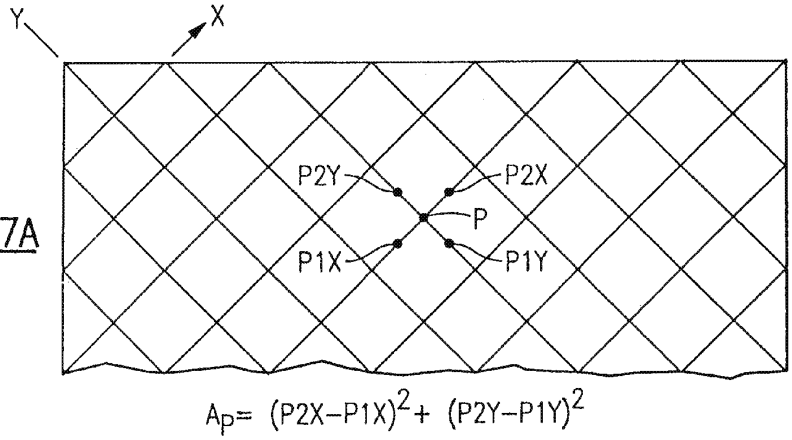


FIG.17B

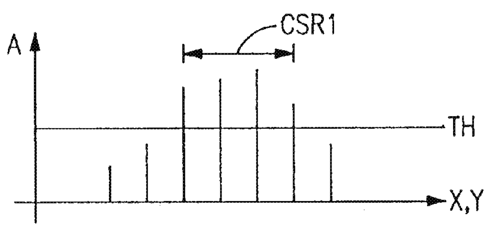
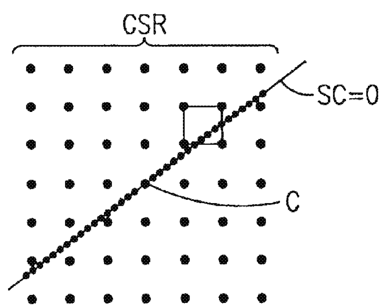


FIG.17C



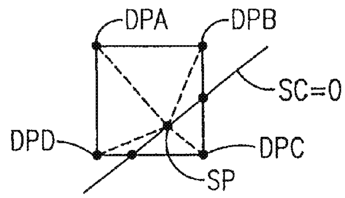
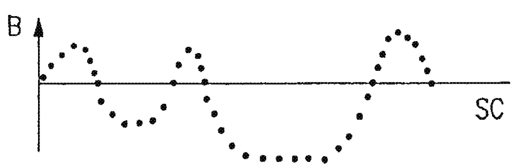


FIG.17D

FIG.17E



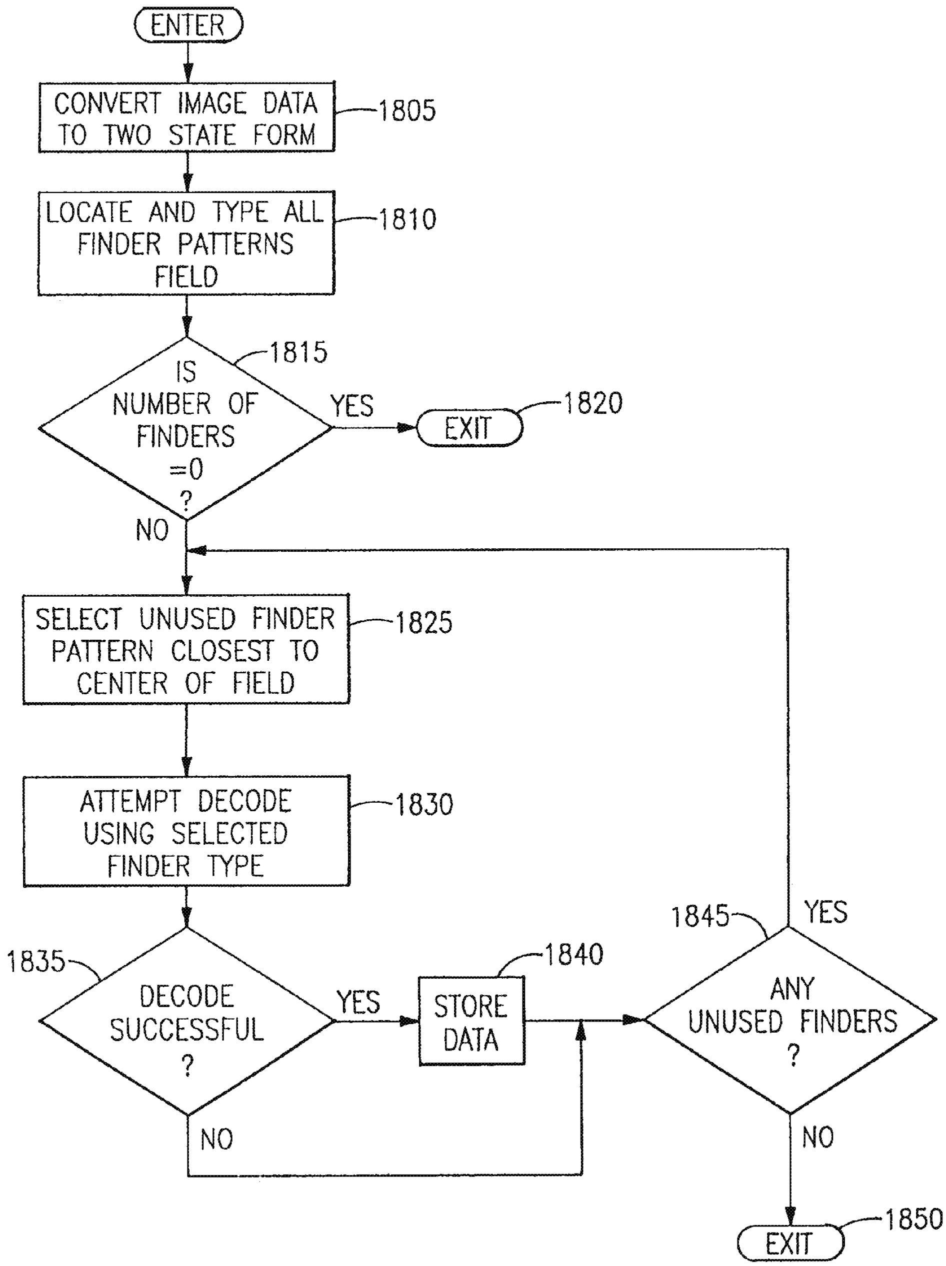

ENTER
CONVERT IMAGE DATA TO TWO STATE FORM
1805
LOCATE AND TYPE ALL FINDER PATTERNS FIELD
1810
IS NUMBER OF FINDERS =0 ?
1815
YES
EXIT
1820
NO
SELECT UNUSED FINDER PATTERN CLOSEST TO CENTER OF FIELD
1825
ATTEMPT DECODE USING SELECTED FINDER TYPE
1830
1835
DECODE SUCCESSFUL ?
YES
STORE DATA
1840
NO
1845
YES
ANY UNUSED FINDERS ?
NO
EXIT
1850

FIG.18

FIG.19A

FIG.19B

FIG.19C

FIG.19D

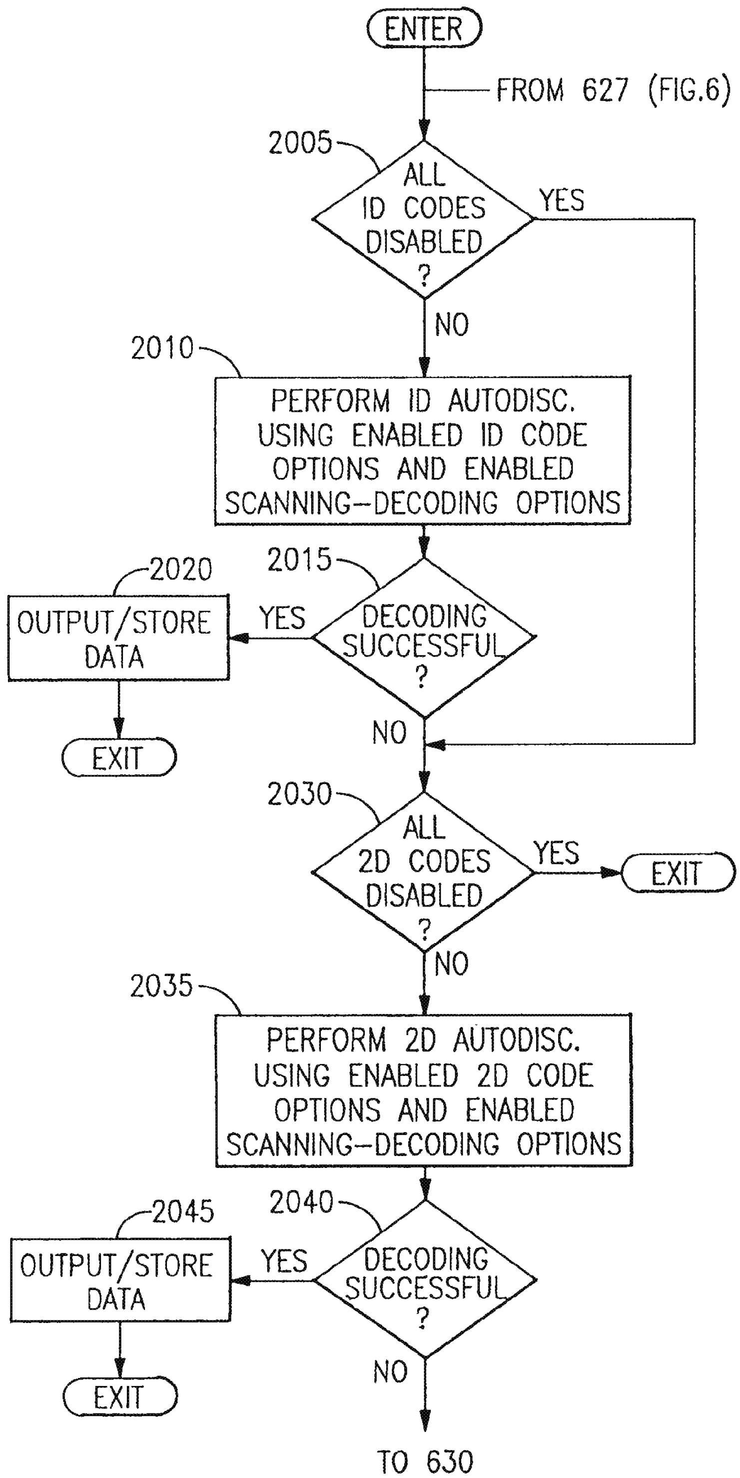

ENTER
FROM 627 (FIG.6)
2005
ALL ID CODES DISABLED ?
YES
NO
2010
PERFORM ID AUTODISC. USING ENABLED ID CODE OPTIONS AND ENABLED SCANNING-DECODING OPTIONS
2020
2015
OUTPUT/STORE DATA
YES
DECODING SUCCESSFUL ?
EXIT
NO
2030
ALL 2D CODES DISABLED ?
YES
EXIT
NO
2035
PERFORM 2D AUTODISC. USING ENABLED 2D CODE OPTIONS AND ENABLED SCANNING-DECODING OPTIONS
2045
2040
OUTPUT/STORE DATA
YES
DECODING SUCCESSFUL ?
EXIT
NO
TO 630

FIG.20

OPTICAL READER SYSTEM COMPRISING LOCAL HOST PROCESSOR AND OPTICAL READER

CROSS REFERENCES TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent application Ser. No. 08/839,020 filed Apr. 23, 1997 (now U.S. Pat. No. 5,965,863) which, in turn, is a continuation-in-part of U.S. patent application Ser. No. 08/697,913, filed Sep. 3, 1996, (now U.S. Pat. No. 5,900,613) which is a continuation-in-part of U.S. patent application Ser. No. 08/516,185 filed Aug. 18, 1995 (now abandoned) which is a continuation-in-part of U.S. patent application Ser. No. 08/205,539 filed Mar. 4, 1994, (now U.S. Pat. No. 5,463,214); said U.S. patent application Ser. No. 08/829,020 is a continuation of U.S. patent application Ser. No. 08/504,643 filed Jul. 20, 1995 (now U.S. Pat. No. 5,773,806); said U.S. patent application Ser. No. 08/697,913 is a continuation-in-part of U.S. patent application No. 08/504,643 filed Jul. 20, 1995 (now U.S. Pat. No. 5,773,806), and a continuation-in-part of U.S. patent application Ser. No. 08/441,446 filed May 15, 1995 (now U.S. Pat. No. 5,591,956), and a continuation-in-part of U.S. patent application Ser. No. 08/371,037 filed Jan. 10, 1995 (now abandoned).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to hand held optical reading devices, and is directed more particularly to a hand held optical reading device configured to be controlled with use of a local host processor.

2. Description of the Prior Art

One dimensional optical bar code readers are well known in the art. Examples of such readers include readers of the SCANTEAM® 3000 Series manufactured by Welch Allyn, Inc. Such readers include processing circuits that are able to read one dimensional (1D) linear bar code symbologies, such as the UPC/EAN code, Code 39, etc., that are widely used in supermarkets. Such 1D linear symbologies are characterized by data that is encoded along a single axis, in the widths of bars and spaces, so that such symbols can be read from a single scan along that axis, provided that the symbol is imaged with a sufficiently high resolution along that axis.

In order to allow the encoding of larger amounts of data in a single bar code symbol, a number of 1D stacked bar code symbologies have been developed, including Code 49, as described in U.S. Pat. No. 4,794,239 (Allais), and PDF417, as described in U.S. Pat. No. 5,340,786 (Pavlidis, et al). Stacked symbols partition the encoded data into multiple rows, each including a respective 1D bar code pattern, all or most all of which must be scanned and decoded, then linked together to form a complete message. Scanning still requires relatively high resolution in one dimension only, but multiple linear scans are needed to read the whole symbol.

A third class of bar code symbologies, known as two dimensional (2D) matrix symbologies, have been developed which offer orientation-free scanning and greater data densities and capacities than their 1D counterparts. 2D matrix codes encode data as dark or light data elements within a regular polygonal matrix, accompanied by graphical finder, orientation and reference structures. When scanning 2D matrix codes, the horizontal and vertical relationships of the data elements are recorded with about equal resolution.

In order to avoid having to use different types of optical readers to read these different types of bar code symbols, it is desirable to have an optical reader that is able to read symbols of any of these types, including their various subtypes, interchangeably and automatically. More particularly, it is desirable to have an optical reader that is able to read all three of the above-mentioned types of bar code symbols, without human intervention, i.e., automatically. This in turn, requires that the reader have the ability to automatically discriminate between and decode bar code symbols, based only on information read from the symbol itself. Readers that have this ability are referred to as "autodiscriminating" or having an "autodiscrimination" capability.

If an autodiscriminating reader is able to read only 1D bar code symbols (including their various subtypes), it may be said to have a 1D autodiscrimination capability. Similarly, if it is able to read only 2D bar code symbols, it may be said to have a 2D autodiscrimination capability. If it is able to read both 1D and 2D bar code symbols interchangeably, it may be said to have a 1D/2D autodiscrimination capability. Often however, a reader is said to have a 1D/2D autodiscrimination capability even if it is unable to discriminate between and decode 1D stacked bar code symbols.

Optical readers that are capable of 1D autodiscrimination are well known in the art. An early example of such a reader is the Welch Allyn SCANTEAM® 3000, manufactured by Welch Allyn, Inc.

Optical readers, particularly hand held optical readers, that are capable of 1D/2D autodiscrimination are less well known in the art, since 2D matrix symbologies are relatively recent developments. One example of a hand held reader of this type which is based on the use of an asynchronously moving 1D image sensor, is described in copending, commonly assigned U.S. Pat. No. 5,773,806, which application is hereby expressly incorporated herein by reference. Another example of a hand held reader of this type which is based on the use of a stationary 2D image sensor, is described in copending, commonly assigned U.S. patent application Ser. No. 08/914,883 (now U.S. Pat. No. 5,942,741), which is also hereby expressly incorporated herein by reference.

Optical readers, whether of the stationary or movable type, usually operate at a fixed scanning rate. This means that the readers are designed to complete some fixed number of scans during a given amount of time. This scanning rate generally has a value that is between 30 and 200 scans/sec for 1D readers. In such readers, the results of successive scans are decoded in the order of their occurrence.

Prior art optical readers operate relatively satisfactorily under conditions in which the data throughput rate, or rate at which data is scanned and decoded, is relatively low. If, for example, the scanning rate is relatively low and/or the data content of the bar code or other symbol is relatively small, i.e., the scanner is operating under a relatively light decoding load, the decoding phase of the reading process can be completed between successive scans. Under these conditions scan data can be accurately decoded without difficulty.

Readers of the above-described type have the disadvantage that, if they are operated under relatively heavy decoding loads, i.e., are required to rapidly scan symbols that have a relatively high data content, the tracking relationship or synchronism between the scanning and decoding phases of the reading process will break down. This is because under heavy decoding loads the decoding phase of a read operation takes longer than the scanning phase thereof, causing the decoding operation to lag behind the scanning operation. While this time lag can be dealt with for brief periods by storing the results of successive scans in a scan memory and decoding the

results of those scans in the order of their occurrence when the decoder becomes available, it cannot be dealt with in this way for long. This is because, however large the scan memory, it will eventually overflow and result in a loss of scan data.

One set of solutions to the problem of maintaining the desired tracking relationship between the scanning and decoding phases of the reading process is described in previously mentioned copending U.S. patent application Ser. No. 08/914,883 (now U.S. Pat. No. 5,942,741). Another set of solutions to the problem of maintaining the desired tracking relationship between the scanning and decoding phases of the reading process is described in U.S. Pat. No. 5,463,214, which issued on the parent application of the last mentioned copending patent application.

Generally speaking, the latter of these two sets of solutions to the above-discussed tracking problem involves the suspension of scanning for brief periods in order to assure that the scanning process does not pull too far ahead of the decoding process. The former of these two sets of solutions to the above-discussed tracking problem, on the other hand, involves the skipping over of one or more sets of scan data, in favor of more current scan data, if and to the extent necessary for tracking purposes, in combination with the use of two or more scan data memories to minimize the quantity of scan data that is skipped.

Prior to the present invention, no consideration has been given to accomplishing scan-decode tracking in conjunction with 1D/2D autodiscrimination, i.e., as cooperating parts of a single coordinated process. This is in spite of the fact that the 1D/2D autodiscrimination is known to involve heavy decoding loads of the type that give rise to tracking problems. Thus, a need has existed for an optical reader that combines a powerful tracking capability with a powerful 1D/2D autodiscrimination capability.

As new and/or improved 1D and 2D bar code symbologies, and as additional 1D and 2D decoding programs come into widespread use, previously built optical readers may or may not be able to operate therewith. To the extent that they cannot operate therewith, such previously built optical readers will become increasingly obsolete and unusable.

Prior to the present invention, the problem of updating optical readers to accommodate new bar code symbologies and/or new decoding programs has been dealt with by manually reprogramming the same. One approach to accomplishing this reprogramming is to reprogram a reader locally, i.e., on-site, by, for example, replacing a ROM chip. Another approach to accomplishing this reprogramming is to return it to the manufacturer or his service representative for off-site reprogramming. Because of the expense of the former and the time delays of the latter, neither of these approaches may be practical or economical.

The above-described problem is compounded by the fact that, if an optical reader is not equipped to operate as a tracking reader, it may not be possible to reprogram it to use an autodiscrimination program that is designed to be executed in conjunction with tracking. This is because the autodiscrimination program may include steps that require the tracking feature to prevent data from overflowing the scan memory and being lost. Alternatively, the scan rate may be decreased, although this reduction will adversely affect performance when low data content symbols are read. Thus, a need has existed for an optical reader that can be reprogrammed economically in a way that allows it to realize the full benefit of the 1D/2D autodiscrimination and tracking features, among others.

SUMMARY OF INVENTION

In accordance with the present invention, there is provided an optical scanning and decoding apparatus and method, suitable for use with bar code readers, bar code scanning engines, and portable data terminals (PDTs), which combines improved scanning-decoding and autodiscrimination features in the context of an apparatus and method which also provides improved menuing and reprogramming features.

In accordance with the menuing feature of the invention, there is provided an improved apparatus and method which enables a user to determine the current operating mode of an optical reading apparatus, and to rapidly and conveniently change that operating mode to optimize it for operation under then current conditions. The menuing feature, for example, enables the user, via a machine readable table of pre-recorded menu symbols, to command the reader to communicate with a host processor using one of a number of protocols, to command the reader to format the decoded output according to host processor requirements, or to command the reader to report to the host processor any of a plurality of types of information about the current operating state of the reader, such as the version of software then being used, the code options that are then being used, and even a complete listing of the reader's parameter table. If a suitable printer is available, the complete status of a first reader may be output as a machine readable menu symbol that other, similarly equipped readers may read and use to reconfigure themselves for operation in the same manner as the first reader.

In accordance with the reprogramming feature of the invention, there is provided an improved apparatus and method by which an optical reader may be reprogrammed from a source external to the reading apparatus, with or without the participation of a user. This external source may be either on-site, i.e., located at the same local facility as the reader, or off-site, i.e., located at a remote facility that is coupled to the local facility only via a transmission line or computer network. When actuated, the reprogramming feature enables a reader to reprogram itself, either in whole or in part, and thereby become able to operate with operating software of the latest type. Depending on the application, the reprogramming of the reader may be initiated either by a host processor external to the reader, as by a command issued via the reader's communication port, or by a user initiated command issued as a part of the above-mentioned menuing process.

In accordance with another aspect of the reprogramming feature, a local host processor may be configured to carry out reprogramming of an optical reader or another type of portable data terminal. In a reprogramming subroutine according to the invention a local host processor can be made, at the selection of a user, to replace an entire main program and parameter table of a reader, or else one of either a main program or a parameter table of an operating program individually.

In accordance with another subprogram of a local host processor, the local host processor can be made to edit a parameter table. When this subprogram is selected the user may either edit the parameter table that is stored in a memory device of the reader or else edit a parameter table stored in a memory device in communication with the local host processor. After editing, the user may write the edited parameter table to the reader's memory device, write the edited parameter to a bulk storage device for later use, or print or display the edited parameter table. In accordance with another aspect of the invention, an optical reader of the invention may be made to receive a component control instruction from a host

processor which is transmitted in response to a user input command to remotely control an optical reader. In accordance with this aspect of the invention, the optical reader is made to execute a component control instruction substantially on-receipt thereof. In one embodiment, execution by an optical reader of a component control instruction has the same effect as a reader trigger being manually pulled.

In accordance with the present invention, there is also provided an optical scanning and decoding apparatus and method which includes improved scanning-decoding and autodiscrimination features, either or both of which may be used in conjunction with, and/or under the control of, the above-described menuing and reprogramming features. In other words, the autodiscrimination feature of the invention is made available to the user on a menu selectable or reprogrammable basis to speed up and/or update the decoding phase of the scanning and decoding process. Together, these features enable the reading apparatus of the invention to read and decode a wide range of optically encoded data symbols at an improved data throughput rate.

When a reader is one in which the scan engine cannot be readily started and stopped, or in which such starts and stops impose unacceptable delays or produce user perceptible flicker, the present invention preferably operates in one of the tracking relationships described in previously mentioned copending application Ser. No. 08/914,883 (now U.S. Pat. No. 5,942,741). One of these tracking relationships is a Skip Scan tracking relationship in which the results of one or more scans may be skipped over entirely in favor of more recently produced scan results. Another is a Decode On Demand tracking relationship in which decoding is suspended briefly as necessary to allow a scan then in progress to be completed. The latter relationship is ordinarily not preferred, but is still useful when the reader is such that its scan memory is able to store only two complete blocks of scan data.

When the reader is one in which the scan engine can readily be stopped, the present invention may operate in the tracking relationship described in previously mentioned U.S. Pat. No. 5,463,214. With this, "Scan On Demand" tracking relationship, scanning is suspended briefly as necessary to prevent scanning and decoding from becoming uncorrelated with one another.

In the preferred embodiment, the reader includes an algorithm that is able to accommodate any of the above-described scanning-decoding relationships, among others. Which of them is actually used will vary from reader to reader depending upon the size and type of memory and the type of scan engine used thereby, and may be changed from time to time.

The present invention also contemplates and provides for at least one scanning-decoding relationship which does not fall within the meaning of the above-defined tracking relationships. One of these non-tracking relationships is a "One Shot" relationship or mode in which a single scan is followed by a single decoding attempt and then a stoppage. Such scanning-decoding events may be initiated by respective single actuations of a manual trigger. Because of its inherently discontinuous nature, the use of the One Shot mode implies the non-use of any of the above-mentioned tracking modes.

Two other such scanning-decoding relationships are referred to herein as the "Repeat Until Done" relationship or mode and the "Repeat Until Stopped" relationship or mode. With the Repeat Until Done relationship, scanning and decoding operations follow one after another until a successful decode occurs, and are then discontinued. With the Repeat Until Stopped relationship, scanning and decoding operations follow one after another and continue, even after sets of decoded data are stored or output, until instructed to stop by the release of the trigger or by the readers' program. Because of their repetitive nature, the use of Repeat Until Done and Repeat Until Stopped modes are usable both in conjunction with the above-described tracking modes and independently of those tracking modes. As a result, the Repeat Until Done and Repeat Until Stopped modes may be implemented as user selectable non-tracking relationships or as tracking relationships.

In embodiments that use the auto discrimination feature of the invention, there is provided a method and apparatus by which a plurality of different symbols of a multiplicity of different types may be scanned and decoded in a manner that is optimized for a particular application, on either a menu selectable or a reprogrammable basis. When all of the symbols to be autodiscriminated are known to be 1D symbols, for example, the data throughput rate may be increased by structuring the autodiscrimination feature of the invention so that no attempt is made to decode 2D symbols, or vice versa. When, on the other hand, the symbols to be autodiscriminated are known to all be of (or all not to be of) a few types, whether 1D or 2D, the data throughput rate may be increased by structuring the autodiscrimination feature so that all but a few (or only a few) 1D and/or 2D symbologies are disabled, i.e., so that no attempt is made to decode them. Other possible autodiscrimination options include not decoding or not outputting data for symbols that encode messages that are too long or too short to be of interest in a particular application. In accordance with the invention, any of these options may be chosen and changed as necessary to achieve the highest possible data throughput rate.

Because of the large number of different combinations of distinct operational states that are made possible thereby, the apparatus and method of the invention will be seen to have a protean quality that not only makes it usable in a large number of different applications, but also enables it to continue to remain so usable as new functions, new bar code symbologies and new and updated decoding programs are developed in the future.

DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will be apparent from the following description and drawings, in which:

FIG. **1** is a block diagram of an embodiment of the reading apparatus of the invention which is generic to reading apparatuses which utilize 1D and 2D image sensors;

FIGS. **2** and **3** are block diagrams of embodiments of the reading apparatus of the invention which utilize 2D and 1D image sensors, respectively;

FIGS. **4**A, **4**B, and **4**C are oblique or partially cutaway views of the 2D reading apparatus of FIG. **2**;

FIGS. **4**D, **4**E, and **4**F are oblique or partially cutaway views of an alternative embodiment of the reader apparatus of FIG. **2**;

FIGS. **4**G, **4**H, and **4**I are oblique or partially cutaway views of another alternative embodiment of the reader apparatus of FIG. **2**;

FIGS. **5**A, **5**B, and **5**C are oblique or partially cutaway views of the 1D reading apparatus of FIG. **3**;

FIG. **6**A is a flow chart of the main program of the reading apparatus of the invention;

FIG. **6**B is a flow chart of a modified main program of the reading apparatus of the invention;

FIG. **7**A shows the structure of one embodiment of a menu word or message suitable for use with the program of FIG. **6**;

FIGS. **7**B and **7**C are tables showing examples of the usages to which various parts of the menu word of FIG. **7**A may be put;

FIG. **8** is a flow chart of the menu routine shown in FIG. **6**;

FIGS. **8**A-**8**D are examples of option symbol selection charts which may be used with the menuing feature of the invention;

FIG. **9** is a block diagram of a typical system with which the reading apparatus of the invention may be used;

FIG. **10**A is a flow chart of a loading routine suitable for use with the invention;

FIG. **10**B is a flow chart of a reprogramming routine suitable for use with the invention;

FIG. **11**A is a flow diagram illustrating a primary program for a host processor configured for reprogramming of, and for other interactions with an optical reader;

FIG. **11**B is a flow diagram illustrating a subprogram for reprogramming an optical reader in communication with a host processor;

FIG. **11**C is a memory map for a memory space having stored thereon an operating program comprising a main program and a parameter table;

FIG. **11**D is a flow diagram for a subprogram executed by a host processor for editing a parameter table;

FIG. **11**E illustrates an exemplary parameter configuration screen;

FIG. **11**F illustrates a flow diagram executed by a host processor for simulating the results of applying editing commands to a decoded message.

FIG. **12** is a timing diagram which shows the scanning/decoding relationship used by the prior art;

FIGS. **13**A through **13**E are timing diagrams which illustrate various ones of the tracking relationships made possible by the present invention;

FIG. **14** shows examples of memory structures that may be used in implementing the tracking relationships shown in FIGS. **13**A through **13**E;

FIG. **15** is a simplified flow chart which illustrates the "Repeat Until Done", "Repeat Until Stopped", and "One Shot" scanning-decoding modes of the invention;

FIG. **16** is a flow chart of one embodiment of the 1D portion of the autodiscrimination program of the invention;

FIGS. **17**A through **17**E are drawings which facilitate an understanding of the flow chart of FIG. **16**;

FIG. **18** is a flow chart of one embodiment of the 2D portion of the autodiscrimination process of the invention;

FIGS. **19**A through **19**D show representative bar code symbols of types that may be decoded by the reading apparatus of the invention; and

FIG. **20** is a flow chart that illustrates the effect of the code options of the autodiscrimination process of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** there is shown a block diagram of an optical reader **10**. As will be explained more fully later, FIG. **1** shows the basic structures that together comprise the general form of an optical reader that is suitable for use in practicing the present invention, and is generic to optical readers that use 1D image sensors and to optical readers that use 2D image sensors. Similarly, FIG. **2** shows the basic structures that together comprise the general form of optical readers that use 2D image sensors. Finally, FIG. **3** shows the basic structures that together comprise the general form of optical readers that use 1D image sensors. Since the present invention is equally applicable to readers that use 1D or 2D image sensors, and to readers that use sensors of either type to read both 1D and 2D symbols, it will be understood that, except where specifically limited to readers having 2D or 1D image sensors, the present description refers generically to readers of any of the types shown in FIGS. **1**, **2** and **3**.

Referring first to FIG. **1**, the optical reader of the invention includes an illumination assembly **20** for illuminating a target object T, such as a 1D or 2D bar code symbol, and an imaging assembly **30** for receiving an image of object T and generating an electrical output signal indicative of the data optically encoded therein. Illumination assembly **20** may, for example, include an illumination source assembly **22**, such as one or more LEDs, together with an illuminating optics assembly **24**, such as one or more reflectors, for directing light from light source **22** in the direction of target object T. Illumination assembly **20** may be eliminated, if ambient light levels are certain to be high enough to allow high quality images of object T to be taken. Imaging assembly **30** may include an image sensor **32**, such as a 1D or 2D CCD, CMOS, NMOS, PMOS, CID or CMD solid state image sensor, together with an imaging optics assembly **34** for receiving and focusing an image of object T onto image sensor **32**. The array-based imaging assembly shown in FIG. **2** may be replaced by a laser array or laser scanning based imaging assembly comprising a laser source, a scanning mechanism, emit and receive optics, a photodetector and accompanying signal processing circuitry.

Optical reader **10** of FIG. **1** also includes programmable control means **40** which preferably comprises an integrated circuit microprocessor **42** and an application specific integrated circuit or ASIC **44**. Processor **42** and ASIC **44** are both programmable control devices which are able to receive, output and process data in accordance with a stored program stored in either or both of a read/write random access memory or RAM **45** and an erasable read only memory or EROM **46**. Processor **42** and ASIC **44** are also both connected to a common bus **48** through which program data and working data, including address data, may be received and transmitted in either direction to any circuitry that is also connected thereto. Processor **42** and ASIC **44** differ from one another, however, in how they are made and how they are used.

More particularly, processor **42** is preferably a general purpose, off-the-shelf VLSI integrated circuit microprocessor which has overall control of the circuitry of FIG. **1**, but which devotes most of its time to decoding image data stored in RAM **45** in accordance with program data stored in EROM **46**. Processor **44**, on the other hand, is preferably a special purpose VLSI integrated circuit, such as a programmable logic or gate array, which is programmed to devote its time to functions other than decoding image data, and thereby relieve processor **42** from the burden of performing these functions.

The actual division of labor between processors **42** and **44** will naturally depend on the type of off-the-shelf microprocessors that are available, the type of image sensor which is used, the rate at which image data is output by imaging assembly **30**, etc. There is nothing in principle, however, that requires that any particular division of labor be made between processors **42** and **44**, or even that such a division be made at all. This is because special purpose processor **44** may be eliminated entirely if general purpose processor **42** is fast enough and powerful enough to perform all of the functions contemplated by the present invention. It will, therefore, be understood that neither the number of processors used, nor the division of labor therebetween, is of any fundamental significance for purposes of the present invention.

With processor architectures of the type shown in FIG. **1**, a typical division of labor between processors **42** and **44** will be

as follows. Processor **42** is preferably devoted primarily to the tasks of decoding image data, once such data has been stored in RAM **45**, handling the menuing options and reprogramming functions, and providing overall system level coordination. Processor **44** is preferably devoted primarily to controlling the image acquisition process, the A/D conversion process and the storage of image data, including the ability to access memories **45** and **46** via a DMA channel. Processor **44** may also perform many timing and communication operations. Processor **44** may, for example, control the illumination of LEDs **22**, the timing of image sensor **32** and an analog-to-digital (A/D) converter **36**, the transmission and reception of data to and from a processor external to reader **10**, through an RS-232 (or other) compatible I/O device **37** and the outputting of user perceptible data via an output device **38**, such as a beeper, a good read LED and/or a display **39** which may be, for example, a liquid crystal display. Control of output, display and I/O functions may also be shared between processors **42** and **44**, as suggested by bus driver I/O and output/display devices **37'** and **38'** or may be duplicated, as suggested by microprocessor serial I/O ports **42**A and **42**B and I/O and display devices **37"** and **38'**. As explained earlier, the specifics of this division of labor is of no significance to the present invention.

Referring to FIG. **2**, there is shown a block diagram of an optical reader which is similar to that of FIG. **1**, except that it includes optical and/or electrical assemblies and circuits that are specifically designed for use with a 2D image sensor. Accordingly, the optical and electrical assemblies and components of FIG. **2** are labeled with the same numbers used in FIG. **1**, except for the addition of the suffix "**-2**". For example, image sensor **32-2** of FIG. **2** is a 2D image sensor which corresponds to generic image sensor **32** of FIG. **1**, imaging optics assembly **34-2** of FIG. **2** is a 2D imaging optics assembly which corresponds to generic imaging optics assembly **34** of FIG. **1**, and so on. In other words, corresponding elements of FIGS. **1** and **2** have corresponding functions, although they may have different shapes and part numbers. Provided that these differences are taken into account, however, the description of the reader of FIG. **1** is equally applicable to the reader of FIG. **2**, and will not be repeated herein.

One specific practical example of an optical reader of the type shown in FIG. **2** may be constructed using the particular commercially available solid-state integrated circuits listed in the following component table:

COMPONENT TABLE - FIG. 2

Block Diagram Item	Manufacturer/Part Number
Image Sensor 32-2	VVL 1060B+
Prog. Gate Array 44-2	Actel 814V40A
Microprocessor 42-2	IDT 3081
EROM 46-2	Intel 28F400VB-B60
RAM 45-2	Toshiba TC51V4265DFT-60

Referring to FIG. **3**, there is shown a block diagram of an optical reader which is also similar to that of FIG. **1**, except that it includes optical and/or electrical assemblies and circuits that are specifically designed for use with a 1D image sensor. Accordingly, the optical and electrical assemblies and components of FIG. **3** are labeled with the same numbers used in FIG. **1**, except for the addition of the suffix "**-3**". For example, image sensor **32-3** of FIG. **3** is a 1D image sensor which corresponds to generic image sensor **32** of FIG. **1**, imaging optics assembly **34-3** of FIG. **3** is a 1D imaging optics assembly which corresponds to generic imaging optics assembly **34** of FIG. **1**, and so on. Provided that these differences are taken into account, however, the description of the reader of FIG. **1** is equally applicable to the reader of FIG. **3**, and will not be repeated herein.

One specific practical example of an optical reader of the type shown in FIG. **3** may be constructed using the particular solid-state circuits listed in the following component table:

COMPONENT TABLE - FIG. 3

Block Diagram Item	Manufacturer/Part Number
Image Sensor 32-3	Toshiba 1201
Prog. Gate Array 44-3	Welch Allyn 21203276-01
Microprocessor 42-3	Motorola HC11
EROM 46-3	Atmel AT 29C257
RAM 45-3	Sony CXK 5864-BM-10LL

Significantly, the above-mentioned structural correspondences between FIGS. **1**, **2** and **3** should not be confused with the types of symbols that may be read thereby. More particularly, the 2D embodiment of FIG. **2** may be used to scan and decode both 1D and 2D bar code symbols. This is because both types of symbols can be imaged by a 2D image sensor. Similarly, the 1D embodiment of FIG. **3** may also be used to scan and decode both 1D and 2D bar code symbols. This is because a 1D image sensor may be used to image a 2D bar code symbol, provided that it is physically moved thereacross during the course of a scan. Because imaging of the latter type is described in detail in copending U.S. patent application Ser. No. 08/504,643, (now U.S. Pat. No. 5,773,806) which has been incorporated by reference herein, that type of imaging assembly will not be discussed again in full herein.

The reader structures shown in FIG. **2** are preferably supported on one or more printed circuit boards (not shown) that are, in turn, supported within a housing.

Examples of types of housings which may be employed to house elements of the reader apparatus shown in FIG. **2** are shown in FIG. **4**A through FIG. **4**I. FIGS. **4**A through **4**C show a first exemplary housing **50-2-1**, FIGS. **4**D through **4**F show a second exemplary housing **50-2-2**, while FIGS. **4**G through **4**I show a third exemplary housing **50-2-3**. Housings **50-2-1**, **50-2-2**, and **50-2-3** are preferably shaped so as to fit comfortably into a human hand, and to include a finger actuatable trigger, **52-2-1**, **52-2-2**, **52-2-3**. Housing **50-2-3** is shown as having an auxiliary trigger **52-2-3'** which may supplement or replace trigger **52-2-3**. Housings **50-2-1** and **50-2-2** have extending therefrom multiconductor cable or tether **54-2-1**, **54-2-2**, for providing communication with a local host processor, whereas **50-2-3** housing has extending therefrom an antenna **55-2-3** for providing a communication with a local host processor. It is seen further that housings **50-2-2** and **50-2-3** have incorporated therein displays **56-2-2**, **56-2-3**, for displaying information to a user, and a keyboard **58-2-2**, **58-2-3**, for inputting data and commands to processor **40**.

FIGS. **5**A–**5**C show a housing **50-3** suitable for housing a 1D reader apparatus of the type described with reference to FIG. **3**. Housing **50-3** includes a finger-actuatable trigger **52-3** and has extending therefrom a cable **54-3** for providing communication with a local host processor. Although not shown as containing such features, it is understood that housing **50-3** could readily be modified to include a display and a keyboard similar to those of 2D reader housings **50-2-2** and **50-2-3**.

Main Program

The overall operation of the reader of FIG. **1** will now be described with reference to the flow chart of FIG. **6**A. As will be explained more fully presently, FIG. **6**A comprises a high level flow chart which illustrates the preferred embodiment of the main program of a reader which uses the apparatus and method of the invention. By "main program" is meant the program that illustrates the relationships between the major subdivisions or subroutines that together implement the above-described features of the invention. It also means the program that illustrates the overall flow and sequence of operations that are responsible for the advantages produced by the invention. Because FIG. **6**A depicts the operation of two processors **42** and **44**, however, operations that appear to be occurring sequentially may actually be occurring "simultaneously". Processor **44** may, for example, be imaging and storing newly scanned blocks of image data in RAM **45** while processor **42** is decoding blocks of image data that were stored in RAM **45** during earlier scans. This is possible because the two processors are operating in different memory spaces, in different time slots, or under the common control of a bus arbitration device. As a result, while the processors can never use the same memory or address space at the same time for conflicting purposes, they can be made to execute their respective programs sufficiently cooperatively and contemporaneously that they are effectively operating simultaneously. It is in this sense that the word "simultaneous" will be used herein.

Referring to FIG. **6**A, the main program begins with block **605** which causes the reader to wait in a low power state until trigger **52** is pulled. When the trigger is pulled, the processor is directed to block **610**, which causes it to power up and initialize the reader hardware, including the ASIC, the DMA channel and the I/O devices, among others. The processor is then directed to blocks **615** and **620** which cause it to define the image data memory space that will be used (block **615**) and to initialize the reader with the default values of the operating parameters stored in the parameter table thereof (block **620**).

The parameter table, which is preferably stored in EROM **46**, specifies the values of the parameters that define the mode in which the reader will operate. Examples of these parameters include the size and the frame rate of the image sensor, the codes that will be enabled during autodiscrimination, the I/O communication protocols, beeper pitch or volume, among others. The default values of these parameters are those which will be used if the user or an externally generated reprogramming command does not specify other values, and correspond to a combination of parameters which are suitable for use under most operating conditions. The different parameters that may be used with the invention, and the effect that they have on the operation of the reader will be discussed in detail later.

After the reader has been initialized, the processor proceeds to blocks **625** and **627**, which call for it to capture and attempt to decode an image of the target symbol. This involves the performance of a number of related steps, the particulars of which are determined by the parameters of the parameter table. Included among these steps are a scanning subroutine which specifies the address space or spaces in which scan data will be stored and whether scanning is to be continuous (e.g., at a full video rate, such as 30 frames per second), or discontinuous (e.g., with pauses related to the current state of the trigger). The operation of the decoding routine, which is executed in a user or factory selectable relationship to the scanning routine, is governed by parameters which control the codes which are enabled for processing as a part of the autodiscrimination process, whether decoding is to be continuous or discontinuous, etc. As will be explained more fully later, permitted combinations of scanning and decoding parameters together define the scanning-decoding relationships or modes which the reader will use.

After exiting block **627**, the processor is directed to block **630** which, if the decoding attempt was not successful, is directed back to block **625** unless the trigger has been released (block **635**) or unless reprogramming request has been received (block **640**), or unless a stop or no-repeat request is called for by the current operating mode of the reader (block **642**). The loop defined by blocks **625**–**642** will be the path repeatedly followed by the processor when autodiscrimination sequences are performed unsuccessfully, and no menuing or programming changes are called for, and no stop request is in effect. If this loop is interrupted by the user's release of the trigger, or by a successful decode, or by a reprogram request, or by a stop request, the reader will be directed by block **635** to stop and wait in a low power state until further processing is called for.

In the above-described loop, block **642** serves the function of stopping the repetitive scanning and decoding of the target symbol in those scanning-decoding modes or under those conditions in which a repetition of scanning and/or decoding is not called for. In the One Shot mode, for example, scanning and decoding are discontinued after one decoding attempt, whether or not that attempt is successful, without regard to the state of the trigger. Similarly, in the Repeat Until Stopped mode, scanning and decoding may be discontinued either by command, via block **642**, or by the release of the trigger via block **635**. Thus, block **642** comprises at least a part of the means by which the reader gives effect to the scanning-decoding parameters of the parameter table.

If block **630** indicates that the last decoding attempt was successful, the processor is directed to a block **645** which calls for a determination of whether the result of the decoding indicates that the decoded symbol was or was not a menu symbol. This determination may be made on the basis of results of the decoding, because all menu symbols are encoded with data that identifies them as such during decoding. If the decoded symbol is not a menu symbol, it is known that the symbol contained data that is to be output by the reader. In the latter event, the processor is directed to block **646**, which causes it to output the data and, proceed to block **647**.

Block **647**, like block **642**, comprises part of the means by which the reader gives effect to the scanning-decoding modes called for by the parameter table. In particular, if decoding is successful (block **630**) and has been output (block **646**), block **647** discontinues scanning and decoding if the Repeat Until Done mode is in effect. If any other mode is in effect, scanning and decoding will continue unless blocks **635**, **640** or **642** call for a different result.

If the decoded symbol is a menu symbol, block **645** directs the processor to perform the menuing routine called for by block **660** before returning to block **635**. As will be explained more fully later in connection with FIG. **8**, the latter routine enables the user to command the reader to perform any of a variety of different tasks, several of which include making user specified changes to the parameter table, thereby changing the operating mode of the reader, and the performance of any of a variety of user specified vector processing routines that do not change the parameter table. Once either of the latter tasks have been performed, the reader is directed to block **635**, which causes it to capture and attempt to decode another image, in accordance with the parameters indicated

by the parameter table, unless instructed to the contrary by blocks **635**, **640** or **642**. Optionally, the execution of menu routine **660** may be followed by a direction back to block **647**, as indicated by dotted line **648**, and the resultant discontinuation of scanning and decoding, if the reader is in its Repeat Until Done mode.

While reprogramming request block **640** has been described as being located between blocks **635** and **625**, it actually preferably represents an externally generated interrupt request that may occur at any time that the reader is operating. Such a request may, for example, be initiated by a local host processor via one of I/O devices **37**, **37'** or **37"**. It may also be initiated by a remotely located processor, via one of the latter I/O devices, through a suitable transmission line or computer network, as shown in FIG. **9**. However the reprogramming request is initiated, it directs the reader to execute the reprogramming routine called for by block **670**. As will be explained more fully in connection with FIG. **10**A, this routine causes the reader to be reprogrammed, either in whole or in part, thereby changing or updating the manner in which it operates and/or the symbols which it attempts to decode.

Menuing

The menuing feature of the present invention will now be described with reference to FIGS. **7**A through **7**C, and the menuing flow chart shown in FIG. **8**.

Turning first to FIG. **7**A, there is shown the format for a menu message or word **650** of the type used by the present invention. This menu word will ordinarily be produced as a result of the decoding of a menu symbol, selected by the user, from a collection of menu symbols printed in a User's Manual supplied with the reader, along with a description of their functions.

Menu word **650** begins with a first one-byte product identification (ID) code field **650-1** that identifies the type and/or model number of the reader. If the decoded product ID code indicates that it is compatible with the menuing program, execution of the menuing program continues normally. If it is not, the processor is caused to exit the menuing routine without making any menu specified changes.

The next field **650-2** of menu word **650** specifies the op code thereof in terms of a number from 0 to 7. This field specifies the operation to be performed by the menu word. The meanings of these different op codes are listed in FIG. **7**C. Among these is op code "**0**", an op code that specifies some task that does not involve a direct change to the parameter table. Such operations will hereinafter be referred to as "vector processing operations". Exemplary ones of the tasks that may be requested pursuant to op code **0** are listed under headings A**1** through A**4** of FIG. **7**C, which tasks may be specified and differentiated from one another by the data included in the data fields **650-3** through **650-7** which follow op code field **650-2**.

Specifically, the vector processing operations comprise selectable menu routines. Vectors to these routines can be stored in a vector table. The contents of data field **650-3**, "offset", is an index to the vector table relative to the base address thereof. If the offset field includes 10 bits, and only five of these bits are used as an index, then 32 different vector values will be possible. In this case the remaining 5 bits may be used for data.

The vector processing operations are preferably made selectable to a user by including respective menu bar code symbols in tables in the User's Manual of the reader. The user may then select the desired vector routine by imaging the appropriate symbol. The manner in which such a table is used will be described later in connection with FIGS. **8**A through **8**D.

Among the vector processing operations which may be selected under op code **0** are the following. Operation A**1** calls for the reader to output, i.e., display or print, via the local host processor, or via an on-reader LCD display, the identity of the version of the software currently being used by the reader. Operation A**2** calls for the reader to output the current contents of the parameter table. Operation A**3** calls for the reader to output the code options that are enabled, e.g., the types of symbols that the reader is to attempt to decode during the autodiscrimination process and whether or not a "multiple symbols option" has been enabled. Other options may also be defined as desired.

Operation A**4** is a particularly powerful and desirable vector processing operation which causes the printer of the local host processor to print a menu bar code symbol that contains all of the information necessary to instruct another reader how it must be programmed if it is to operate in the same manner as the current reader. This, in turn, enables the user to quickly set up the same (or another) reader to operate in a manner that would otherwise require the user to manually select an entire sequence of parameter table values. If it is used to set up other readers, the process of using such a menuing bar code symbol may be thought of as a "cloning" procedure, since it allows a multiplicity of readers to be identically configured.

The type of bar code symbol in which the parameter table is printed must naturally be in a bar code symbology in which the reader is able to both encode (or write) data and decode (or read) data. Because the parameter table has a data content which may be too high to be encoded in many 1D symbologies, the menu symbol encoding the parameter table is preferably encoded in a 2D bar code symbol. One 2D symbology which is particularly suitable for use in encoding a menu bar code symbol of the subject type is that developed by Welch Allyn, Inc. and referred to as the "Aztec" symbology. The manner in which data is encoded in accordance with the Aztec symbology is described in detail in copending, commonly assigned U.S. Pat. No. 5,591,956, which is hereby expressly incorporated herein by reference.

In addition to op code **0**, menu word **650** also makes available op codes **1**–**7**, as shown in FIG. **7**C. The latter op codes comprise simple commands, each of which specifies a change that is to be made at a particular part of the parameter table, using specified data, if required. Assuming that parameter values are stored as bytes in respective addresses of the memory that are set aside for use as a parameter table, offset field **650-3** will comprise an index to the parameter byte relative to the base address of the table. The data or data mask that is to be used with the specified offset is specified by the data contained in up to four 8 bit data fields **650-4** through **650-7** of menu word **650**.

Referring to FIG. **7**C, for example, op code "**1**" specifies a "clear" operation. It directs the processor to the byte of the parameter table that is pointed to by the offset field, and uses the content of data field **650-4**, Data **0**, to specify the bit mask that is to be used to specify the bits to be cleared. Op code "**6**", on the other hand, specifies a load operation. It directs the processor to the byte of the parameter table that is pointed to by the offset field, uses Data **0** as the bit mask for the bits to be changed, and uses Data **1** as the new data for those bits. Because the use of op codes of this type are known to those skilled in the art, the use of these op codes will not be described in detail herein.

In accordance with the invention, the parameter table is used to specify the operating options that are made subject to

the control of the user. Representative groups of such options are shown as headings A through E of FIG. 7B, together with some of the options that may be selected under those headings. One important group of those options are those that are labeled as "code options" under heading B. Under this heading may be found the parameter table addresses that are set aside for use in specifying the enabled/disabled states of the various decoding programs that may be used during the autodiscrimination process of the invention. The parameter table addresses corresponding to options B**1** and B**2**, for example, may be set aside for specifying whether all 1D codes or all 2D codes are or are not to be used in an attempt to decode an unknown symbol during autodiscrimination. Similarly, the parameter table address corresponding to option B**3**, may specify a particular bar code symbology, such as MaxiCode, that is to be enabled or disabled, i.e., specify whether the autodiscrimination process is or is not to include an attempt to find a MaxiCode symbol in an image. In addition, the parameter table address corresponding to option B**4** may indicate that after decoding, messages that are longer than a specified maximum length or shorter than a specified minimum length are not to be output. Depending on the application, this Min-Max length option may be applied on a symbology dependent basis, i.e., applied so that it is active with some symbologies, but not with others, or may be applied on a symbology independent basis. Finally, the parameter table address corresponding to option B**5** specifies whether the Multiple Symbols option of the invention is or is not to be used. The enablement of this option, which given effect by block **643** of FIG. **6**A, calls for the reader to attempt to decode more than one symbol in the field of view of the reader without having to acquire multiple images of that field of view. The types of options selected for inclusion under heading B will vary from application to application, and the present invention will be understood not to be restricted to any particular selection of such types.

The inclusion of user selectable code options as part of the menuing process of the invention has a significant effect on the overall data throughput rate of the reader, i.e., on the time necessary to decode a symbol whose symbology is not known in advance. If, for example, it is known that none of the symbols to be read during a series of readings comprise 1D symbols of any type, or any subset of 1D symbols such as Codabar, Code 39 or Code 128, code options allow a user to direct that any attempt to decode an unknown symbology according to these symbologies is to be skipped, thereby shortening the total time necessary for the processor to decode the unknown symbol according to the symbology which it does use. This skipping also reduces the chances of a misread. If, on the other hand, it is known that all of the symbols to be read during a series of reading operations are of one type, such as Interleaved 2 of 5, all 2D decoding programs and all the decoding programs for 1D symbologies other than interleaved 2 of 5 may be disabled, thereby limiting all decoding attempts to a single 1D symbology. Thus, the menuing process of the invention allows the autodiscrimination process of the invention to be optimized so as to achieve the highest possible data throughput rate.

A second important group of options provided by the menuing process of the invention are those that are labeled as "Scanning-Decoding" Options under heading C of FIG. **7**B. Unlike the code options of heading B, the scanning-decoding options of heading C are not concerned with which codes are enabled or disabled, but rather with the relationships which will be allowed to exist between scanning and decoding. The parameter table address corresponding to option C**1**, for example, may be used to specify that the reader operate in a "One Shot" scanning-decoding mode. In this "One Shot" mode the reader will scan and attempt to decode one bar code symbol each time that the trigger is depressed and then stop. The address spaces corresponding to scanning-decoding modes C**2** and C**3**, on the other hand, may be used to specify that the reader operate in a "Repeat Until Done" (RUD) or "Repeat Until Stopped" (RUS) scanning-decoding mode. In these modes, the reader will scan repeatedly and attempt to decode repeatedly until there is a successful decode (RUD), or until requested to stop whether or not there is a successful decode (RUS). Scanning-decoding modes C**1**–C**3** are preferably made user selectable by including suitable menu symbols in the User's Manual.

Also included among the scanning-decoding modes of the invention are the tracking modes listed under headings C**4**–C**6** of FIG. **7**B. Of these, the Scan On Demand (SOD) mode C**4**, when enabled, causes decoding to proceed continuously while scanning is started and stopped as necessary to maintain a tracking relationship between scanning and decoding. Skip Scan (SS) scanning-decoding mode C**5**, when enabled, causes the results of older scans to be discarded in favor of more current scans when and as necessary to maintain the desired tracking relationship between scanning and decoding operations. Finally, Decode On Demand (DOD) scanning-decoding mode C**6**, when enabled, causes scanning to proceed continuously while decoding is started or stopped as necessary to maintain a tracking relationship between scanning and decoding. The particular one of these tracking modes that will be used is preferably set during manufacture, based on the amount of image data memory that is present within the reader, and not changed thereafter. There is no reason in principle, however, why tracking options C**4**–C**6** cannot be made user selectable as, for example, by the inclusion of suitable menu symbols in the User's Manual.

The availability of the SOD, SS and DOD tracking modes among the scanning-decoding options that may be selected during the factory programming of the reader is beneficial since it allows the data throughput rate of the reader to be optimized in view of the amount of memory that is available within the reader. At the same time, because operation in all of these modes may be disabled during operation in the One Shot, Repeat Until Done, or Repeat Until Stopped modes, the reader is able to operate in accordance with the non-tracking variants of these modes when such operation is preferred. One condition under which such operation may be preferred is one in which scanning while decoding is slow as a result of the time sharing of a bus. Thus, the reader of this invention combines flexibility of use with time-optimized use of the scanning and memory resources of the reader.

As will be explained more fully later, the RUD and RUS modes may be used either with or without one of the above-described tracking modes. This is because repetition is a necessary but not a sufficient precondition to the use of the tracking modes of the invention. Accordingly, if the RUD or RUS mode is not used in conjunction with a tracking mode it will comprise a non-tracking mode. If the RUD or RUS mode is used in conjunction with a tracking mode it will comprise a tracking mode.

Other groups of options that are provided by the menuing feature of the invention include those that are set aside under headings A, D and E of FIG. **7**B. Of these Communication Options, heading A, is associated with parameter table addresses that correspond to various communication modes that may be used by the reader. Included among these options are A**1**, an option that enables/disables RS-232 communication through an I/O device (such as I/O **37**, **37'**, etc.), A**2** which specifies the baud rate of the selected communications mode,

and A**3** which enables/disables the RF link that the reader may use in place of multi-conductor cable **54-2** of FIGS. **4**A–**4**C. Option A**4** is an example of a network option which specifies the type of computer network with which the reader is to operate, in this case ETHERNET, although other types may also be provided for.

Similarly, heading D is associated with parameter table addresses that correspond to various miscellaneous operating options that may be selected by the user. Included among these options are D**1** which enables/disables the beeper and allows the volume thereof to be adjusted, D**2** which enables/disables the use of an aiming LED, and D**3** which enables/disables the provision of aural feedback to the user, among others. An example of a reader which provides aural feedback is described in U.S. Pat. No. 5,420,409.

Heading E is associated with parameter table addresses that correspond to various transmission options that may be selected by the user. Included among these options are E**1** and E**2**, which enable/disable the outputting of check characters or checksum data with decoded data, and E**3** which enable data edit options such as adding a carriage return and/or a line feed and/or other ASCII characters to the decoding data. Options E**1** and E**2** are useful, for example, in the localization and identification of hardware or software failures during the servicing of the reader. Option E**3** is useful in placing decoded data in a form suitable for use with an application program.

Heading F is associated with parameter table addresses that correspond to various message editing commands for editing the form of characters in a decoded message. These commands may be, for example, search and replace commands (option F**1**), commands to insert characters (option F**2**), commands to delete characters from a decoded message (option F**3**), or other commands.

Heading G, meanwhile, is associated with parameter table addresses that correspond to commands for adding prefixes or suffixes, of a selectable character length, to a decoded message. Prefixes and suffixes are added to messages so that the host processor can identify the source of, or other characteristics of received messages. Option G**1** allows addition of a prefix to a decoded message while option G**2** allows addition of a suffix to a decoded message.

In view of the foregoing, it will be seen that the menuing process of the invention provides a wide range of user selectable functions and modes that allow the reader to be tailored to a user's specific application and/or preferences. Among these, the code options and the scanning-decoding options in particular, allow a user to reconfigure the operation of the reader in ways that have not heretofore been possible and thereby substantially increase the flexibility and overall data throughput rate of readers that practice the present invention.

The manner in which the invention can be updated to accomplish the above-described results will now be described with reference to the flow chart of FIG. **8**, which shows the steps included within menu routine block **660** of FIG. **6**A. The menu routine of FIG. **8** begins with a block **805** which causes the processor to convert the decoded menu symbol message into hexadecimal form. This has the effect of formatting the message so that the fields of the menu word are expressed as pairs of hexadecimal digits. Once this has been done the processor examines the product ID code to verify that it is compatible with the reader being menued. If it is not, the processor is directed to exit the menuing routine and continue scanning. If it is, the processor is directed to block **810** which distinguishes those menu messages which contain op codes from those which contain numerical data but no op codes. If there is no op code, the processor is directed to block **815**, which causes it to collect in an accumulator all of the digits of the message for later use before proceeding to block **850**. An example of numerical data without an op code comprises the minimum or maximum length of the messages that are to be output under code option B**4**.

If the menu message contains an op code, and the op code is other than 0, the processor is directed, via block **820**, to a block **825**. The latter block causes it to make the parameter table changes called for by the op code and the associated offset and data fields, sets a "flash" flag to indicate that changes have been made and then proceeds to block **850**. This has the effect of implementing the user selected changes in the menuing options discussed previously in connection with FIG. **7**B. Such changes will ordinarily be made in a copy of the parameter table that is stored in RAM **45**, and then later transferred to EROM **46**.

If the menu message contains an op code of 0, the processor is directed, via block **820**, to a block **830**. The latter block causes the processor to perform the vector processing operation indicated by the remainder of the message. This operation will comprise one of the operations discussed previously in connection with items A**1** through A**4** of FIG. **7**C, among others, before proceeding to block **850**.

In view of the foregoing, it will be seen that, when the processor arrives at block **850** it will have taken all required numerical data, performed all required parameter table modifications, or performed all required vector processing operations. As will now be explained, the remainder of the flow chart of FIG. **8** is directed to storing a semi-permanent copy of the parameter table in EROM **46**.

If, on arriving at block **850**, the processor finds that the "flash" flag has not been set, it knows that the contents of the parameter table have not been changed and, consequently, that no updated copy thereof needs to be stored in EROM **46**. Under this condition, the processor is directed to simply return to the main program of FIG. **6**A. If, on arriving at block **850**, the processor finds that the "flash" flag has been set, however, it knows that the contents of the parameter table have been changed and, consequently, that an updated copy thereof needs to be stored in EROM **46**. Under this condition, the processor is directed to blocks **855**, **860** and **865**, which defines the steps necessary to store this updated copy.

In accordance with block **855**, the processor is instructed to copy from EROM **46** to RAM **45**, the program instructions (flash routine) necessary to copy the parameter table from RAM to EROM. The copying of the flash routine to RAM is necessary because the EROM cannot be written to when the apparatus is reading or operating from the EROM. Once the flash routine has been copied to RAM **45**, the processor is directed to jump to RAM to begin executing that routine. As it does so it is directed, via block **860**, to erase the old (unchanged) parameter table from EROM **46**. Per block **865**, it then copies new (changed) parameter table from RAM **45** to EROM **46**. Once this has been done, the processor is directed back to the main program of FIG. **6**A to begin operating in accordance with the operating mode specified by its new parameter table. Thus, the performance of the steps called for by blocks **855**–**865**, when called for by block **850**, has the effect of partially reprogramming the reader so that it operates in the manner indicated by the last menuing symbols selected by the user.

Referring to FIGS. **8**A–**8**D, there are shown examples of menu symbol selection charts of the type that may be used with the present invention. Referring first to FIG. **8**A, there are shown two parts of an option selection or menu chart that is used to enable and disable two exemplary 1D bar code symbologies, namely: Code 128 and UPC A. If a user wants to enable the decoding of Code 128 symbols, he need only

image menu symbol **802** which, in the present example, is a 2D bar code symbol expressed in the Aztec bar code symbology. Conversely, if a user wants to disable the decoding of Code 128 symbols, he need only image menu symbol **804**. Similarly, imaging symbols **806** or **808** enables or disables the decoding of UPC A symbols. Advantageously, the change called for by the user is accomplished as the result of a single imaging step, rather than as a result of multiple imaging steps.

Referring to FIG. **8**B, there are shown two parts of an option selection chart that is used to select the desired one of the baud rates that may be used by the reader's I/O devices. A user chooses the desired one of the exemplary 1200, 9600, 19200 and 38400 baud rates by simply imaging the corresponding ones of menu symbols **812** through **818**. Again, the change is accomplished as the result of a single imaging step.

The fact that the above-discussed examples of menu selections make use of menu symbols that use the Aztec 2D symbology is not essential to the practice of the invention. Other 2D or 1D menu symbol symbologies could also have been used, if desired, as will be seen from the following discussion of FIGS. **8**C and **8**D. What is important is that the symbology used for the menu symbols be the one that is correct for the model indicated by the product ID field of the menu word. In the case of FIGS. **8**A and **8**B, the illustrated menu symbol symbology is that which is used by the IMAGETEAM® Model 4400 reader manufactured by Welch Allyn, Inc.

Referring to FIG. **8**C, there are shown exemplary parts of the option selection or menu chart that can be used with Welch Allyn SCANTEAM® readers. In FIG. **8**C, symbol **822** is an example of a menu symbol that, if imaged, causes all Code 11 and Code 128 settings to assume their default values. Symbols **824** to **836** are examples of menu symbols that allow Code 11 options to be enabled and disabled on an individual basis. Similarly, symbols **848** to **856** are examples of menu symbols that allow Code 128 options to be enabled and disabled on an individual basis.

Referring to FIG. **8**D, there are shown further exemplary parts of the option selection or menu chart that may also be used with Welch Allyn SCANTEAM® readers. In FIG. **8**D symbol **858** is an example of a menu symbol that, if imaged, causes the settings for one of the RS-232 ports of the reader to assume their default values. Symbols **862** and **864** are examples of menu symbols that enable and disable a CTS check selection feature. Finally, symbols **866** through **884** are examples of menu symbols that allow any of a number of different baud rate selections to be made. Once again, the present invention allows all of these menu selections to be made by means of a single step selection process.

Because fuller information concerning the menu options contemplated by the present invention, and their uses is contained in the User's Manual for the above-identified readers, these menu options will not be discussed further herein.

Reprogramming

In accordance with another feature of the apparatus and method of the invention, the reader may be reprogrammed to operate in accordance with an entirely new application program. This means that the reader may not only be provided with a new or updated decoding program, or a new parameter table, it may also be provided with one or both of a new menuing routine and a new main program. As a result, a reader may be effectively reconfigured as a new reader, with new capabilities and features, as often as necessary to keep it up to date with the latest developments in optical reader technology. Advantageously, this reprogramming may be accomplished either locally as, for example, by a local host processor equipped with a diskette or CD-ROM drive, or remotely by a distant processor that is coupled to the reader via a suitable telephone or other transmission line or via a computer network or bulletin board.

The reprogramming feature of the invention will now be described with reference to the system block diagram of FIG. **9** and the reprogramming flow chart of FIG. **10**A. Referring first to FIG. **9** there is shown a reader **10**, of the type shown in FIG. **4** or **5**, which is coupled to a local host processor **900** by means of multi-conductor flexible cable **54**. The reader may also comprise a cordless battery powered reader **10'** which is coupled to a host processor **900** via a suitable RF link including antennae **905** and **910** and an RF interface module **915**. Host processor **900** is preferably equipped with a display **930** by which the results of the previously described vector processing operations may be displayed, and with a printer **940** by which the previously described menuing bar code symbol may be printed. As used herein, the term "local host processor" will be understood to include both stand alone host processors and host processors which comprise only one part of a local computer system.

If the new reader program is available locally as, for example, on a diskette or CD-ROM, it may be loaded into reader **10** or **10'** using a suitable drive unit **920**, under the control of a keyboard **925** and the reprogramming routine shown in FIGS. **10**A and **10**B. In addition to drive unit **920**, processor is typically in communication with a read only program storage device such as a ROM **921** and a read/write storage device such as a RAM **922**. If the new reader program is available at a remotely located processor **950**, it may be loaded into reader **10** or **10'** through a suitable transmission link **955**, such an electrical conductor link, a fiber optic link, or a wireless transmission link through a suitable communication interface **960**, such as a modem. As used herein, the term "transmission link" will be understood to refer broadly to any type of transmission facility, including an RS-232 capable telephone line, as called for by communication option A**1** of FIG. **7**B, an RF link, as called for by communication option A**3** of FIG. **7**B, or a computer network, e.g., ETHERNET, as called for by communication option A**4** of FIG. **7**B, although other types of transmission links or networks may also be used. For example, transmission link **955** could be provided by a coaxial cable or any other non-RF electromagnetic energy communication link including a light energy infrared or microwave communication link. Link **955** could also be an acoustic communications link. Additional communication options include a baud rate option A**2** which allows different baud rates to be selected.

The manner in which the reader of the invention may be made to perform any of a variety of different externally specified functions, including reprogramming itself, will now be described with reference to the flow charts of FIGS. **10**A and **10**B. As will be explained more fully presently, the flow chart of FIG. **10**A is a flow chart by which a program originating outside of the reader may be loaded into the reader for execution thereby. One example of such an externally originated program is the reprogramming program shown in FIG. **10**B. Other examples of such externally originated programs may include diagnostic or test programs, among others.

Turning first to FIG. **10**A, this flow chart is entered when the reader receives an externally generated command, such as the six character sequence BBOOTT, which it is programmed to recognize and respond to. This command may be initiated either by a local or a remotely located processor and transmitted to the reader via any of the I/O devices shown in FIG. **1**. It may, for example, be initiated by the local host processor via keyboard **945** or by remote processor **950**. This command

may be given effect as an interrupt request and recognized as such by decision block **1005** of FIG. **10**A. It will be understood that while interrupt block **1005** is shown in FIG. **10**A, it may in fact be located at any point within the main program of the reader.

Once the BBOOTT command has been received and acted on, the processor enters a loading loop including blocks **1007** through **1020**. This loading loop causes the processor to load a program into RAM, one line at a time, in conformity with any suitable communication protocol, until the last line of code is detected via block **1020**. When the latter has occurred, the processor is directed to block **1025**, which causes it to jump to the newly received program and to begin executing the same before returning to the main program.

Referring to FIG. **10**B, there is shown an exemplary flow chart for a reprogramming routine suitable for use in reprogramming the reader to operate with new or different decoding programs, and or new or different menuing programs, among others. This program is an example of a program which may be executed as a result of the execution of the loading loop **1007**–**1020** of FIG. **10**A, and which begins to be executed as the processor enters block **1025** of FIG. **10**A.

On executing the reprogramming flow chart of FIG. **10**B, the device loads the program that is intended to replace all or part of the program currently stored in EROM. This process begins as the processor encounters block **1035**, which directs it to wait until a line of externally generated code is received. As each line of code is received, it is first checked for correctness (e.g. checksum), as called for by block **1040** and, if an error is found, sends a negative acknowledgment signal to the sending processor per block **1045**. Each time that a correct line of code is received, the flow loops back for additional lines until the last line of the current file has been correctly read, as called for by block **1050**. Since the last line of the file does not contain program data, and cannot occur until all blocks of program data have been processed, block **1050** will direct the processor to block **1060**, unless and until all blocks of program data have been received and stored in EROM **46**, and then cause it to return to the main program of FIG. **6**A via exit block **1055**.

If the processor has not exited the reprogramming routine of FIG. **10**B per blocks **1050** and **1055**, block **1060** will cause it to determine if the last received line indicated that a new block has begun. If it has, the processor is directed to block **1065**, which causes it to erase that new block of EROM before continuing to block **1070** and storing that last received line therein. If it has not, block **1070** will cause the processor to store the last received line to the last erased block of EROM. If this line has been successfully stored, as determined by block **1075**, the processor will acknowledge that fact per block **1077** and loop back for another line.

If, however, any line of data has not been successfully stored, block **1075** will direct the processor to a block **1080** which causes it to output an error message and exit the program. If the latter occurs, the reprogramming routine as a whole must be repeated. If the latter does not occur, the above-described process will continue line-after-line, block-after-block, until the entire file has been successfully transferred.

In view of the foregoing, it will be seen that the effect of the reprogramming routine of FIG. **10**B is to attempt to reprogram part or all of EROM **46** as requested, or to continuing the attempt to do so until it either succeeds or fails. To the extent that the reader is reprogrammed, it will effectively become a new or updated reader. This is not only because this reprogramming can not only modify the parameter table, it can also modify the decoding or other programs referenced by the parameter table and the menuing program itself. Thus, the reprogramming feature can not only change the manner in which the reader operates, it can also change the manner in which the operation of the reader can be modified in the future.

With the use of the above-described reprogramming feature, the reader of the invention may be kept current with the latest available programs that are suitable for use therewith. A user at local processor **900** may, for example, communicate with remote processor **950**, via keyboard **925**, and determine if new programmable features are available. If they are, he may obtain them from the remote process and download them locally, or request that the remote processor download them directly to the reader. Alternatively, the remote processor may initiate the reprogramming of the reader independently as, for example, pursuant to a service contract or updating service. It will be understood that all such embodiments are within the contemplation of the present invention.

Local Host and Reader System Operations

As has been described hereinabove, reprogramming of a reader may be accomplished with use of a local host processor. This section describes additional features of a system comprising a local host processor **900** and a reader **10** according to the invention, and more particularly describes features and additional system operations that are realized by various interaction between host processor **900** and reader **10**, and in certain applications by a host processor **900** that is not in communication with a reader **10**.

A flow diagram illustrating the primary program for operating a local host processor for use in controlling a reader is shown in FIG. **11**A. By executing block **1102** host processor causes to be displayed on a display monitor **930** a subprogram option screen. The subprogram option screen displays various subprogram options for a user to select. Selection of one subprogram option causes a series of instructions pertaining to that particular option to be executed by local host processor **900**. These subprograms of a host primary program controlling local host processor may include, for example, a subprogram for reprogramming a reader; a subprogram for uploading parameter information from a reader to host, or information pertaining to a main program presently operating a reader; a subprogram for instructing a reader to perform self-diagnostic testing; a subprogram for determining the reader's main program revision level; a subprogram for outputting parameter table information, possibly to auxiliary readers; a subprogram for editing parameters of a parameter table; a subprogram for simulating the result of applying editing commands to a decoded message; and a subprogram for displaying barcode symbols for scanning by a reader.

A flow diagram illustrating a subprogram for reprogramming of a reader **10** by control of a local host processor is shown in FIG. **11**B. Whereas FIGS. **10**A and **10**B illustrate instructions executed by processor **40** of reader **10** for providing reprogramming of a reader, FIG. **11**B illustrates instructions executed by local host processor for providing reprogramming of a reader.

At block **1110** host processor **900** displays a main reprogramming screen on display monitor **930**. The main reprogramming screen prompts a user to designate a source for an operating program. The source designated is typically a bulk storage device such as a hard or floppy disk drive but also may be, for example, a RAM or ROM storage device. When the source is selected, host processor **900** displays on display monitor **930** indicators of the operating programs, or files, that are available in the storage device source selected (block

1114) and a user selects one of the operating programs. Some available operating programs comprise entire main programs and entire parameter tables for loading into reader, whereas other available operating programs include only parameter tables which may be customized parameter tables created by a user during execution of a parameter table editing subprogram.

When a user selects a source for an operating program, and selects a desired operating program, downloading of the operating program proceeds. At block **1116** host processor determines whether a reader is connected to the host processor communications link, normally by serially transmitting a device detection command to a reader, which has been previously programmed to transmit an acknowledge response message on the reception of a detection command.

If a reader is connected to host processor **900** then host processor at block **1118** sends an identification command to reader **10** which is previously programmed to transmit an identification response on the reception of an identification command. After receiving the identification response and comparing the response to the selected operating program at block **1120** processor at block **1122** determines whether the reader is of a type which is compatible with the selected operating program. An operating program is compatible with a reader in communication with host processor if the operating program is specifically adapted for that reader's unique hardware configuration. Bar code reader's of various types have different hardware components including different memory devices, image sensors, input/output devices, and other components. The selected operating program must be in a form enabling it to communicate with the particular hardware components of the presently connected reader.

If the selected operating program is compatible with the present reader, the host processor at block **1126** determines if the operating program is a parameter-only type operating program or an operating program that comprises a main program and a parameter table. This determination can be made, for example, by reading the contents of a DOC type file which is made to be read by processor **900** when an operating program is read, and which is made to include an identifier as to whether the operating program is of a type which includes a main program and parameter table; by reading the contents of a predetermined address of the operating program which is made to include an identifier as to the type of operating program; or by reading predetermined addresses of an operating program designated for storing a main program and basing the determination on whether instructions are present in the designate addresses.

A memory map for a typical operating program in accordance with the invention is shown in FIG. **11**C. When an operating program is stored in a memory device, which may be, for example EROM **46** of reader **10**, or a disk drive **920** or other storage device associated with host processor **900** a plurality of first predetermined address locations e.g. 000 to 5000 of the storage device are designated for storing parameters of the main program, while a plurality of second predetermined address locations e.g. 8000 to 9000 are designated for storing instructions of a parameter table. The beginning and end addresses of the parameter table may change from operating program to operating program. However, the parameters of each parameter table are in identical locations with respect to the beginning address.

When host processor **900** determines at step **1126** that the selected operating program includes a main program then program control proceeds to step **1130** wherein processor transmits the contents of the selected operating program into EROM **46** of reader **10**. If host processor **900** determines at block **1126** that the selected operating program is a parameter only type operating program then host processor **900** first queries EROM **46** to determine the begin and end address locations of the parameter table of the operating program currently stored in EROM. To this end host processor **900** at block **1130** polls the contents of a vector pointer table **1134** in predetermined address locations of EROM. Described previously herein vector pointer table **1134** comprises the beginning and end addresses of the parameter table. After vector pointer table is polled, host processor **900** stores the address location of the present parameter table, modifies the parameter table address of the selected parameter-only operating table in accordance with the parameter table addresses of the existing parameter table (block **1136**) and writes the contents of the parameter table address locations of the modified parameter-only type operating program into EROM **46** (block **1140**).

If processor **900** determines at block **1126** that the selected operating program is of the type having a main program and a parameter table, then processor **900** at block **1144** prompts the user whether the user would like to save the contents of a parameter table of the operating program currently stored in EROM **46** of reader **10**; that is, utilize the parameters of the current operating program in the operation of a reader that is programmed to have a new main program. If the user responds affirmatively, then processor **900** reads the contents of the existing parameter table (block **1150**) after first polling the vector pointer table and then writes, at block **1152**, the contents of the existing parameter table in a predetermined holding address location of a storage device associated with processor **900** or reader **10**.

The selected operating table is then written into EROM **46** at block **1140**, line by line, until loading is complete. If the user had requested at block **1144** to save the contents of the original parameter table (a determination made at block **1153**), then processor **900** writes the contents of the parameter table stored in a holding address location to the appropriate parameter address locations of EROM at block **1154**, after determining the address locations of the parameter table at block **1156**.

Referring again to the primary host processor program shown in FIG. **11**A, another subprogram which can be selected from subprogram option screen displayed at block **1102** is a subprogram for editing a parameter table via host processor control. An important feature available in this subprogram is that the subprogram allows a user to edit a parameter table read from a memory location of processor **900** or reader **10** without there being a reader currently in communication with processor **900**, thus improving the convenience of operation.

As discussed previously with reference to FIG. **7**B, a parameter table is used to specify operating options that are subject to the control of the user. During execution of instructions of a reader's main program stored in a first predetermined memory locations of a storage device, parameters of a parameter table, which is stored in a second predetermined set of memory address locations of a storage device, are called up with use of lookup type instruction as exemplified by representative lookup instruction (in pseudocode) **1160** shown in FIG. **11**C. Parameters of a parameter table may be, for example, communications option parameters (subheading A), code option parameters (subheading B), scanning-decoding option parameters (subheading C), operating option parameters (subheading D), transmit option parameters (subheading E), data formatter command parameters (subheading F), prefix/suffix parameters (subheading G), or other types of parameters.

A flow diagram for a parameter table editing subprogram is shown with reference to FIG. **11**D. At block **1162** processor **900** determines if a reader is in communication with processor **900** in the fashion described previously with reference to block **1116** of FIG. **11**B. If a reader is present, processor **900** at block **1166** reads the parameter table presently stored in EROM **46** (after determining the table's location), along with a list of analog waveform outputs from another predetermined memory location from EROM **46**. A list of possible types of analog waveform outputs a reader may be configured to generate allowing the reader to transmit data to various types of terminals is stored in a predetermined waveform list memory location. The waveform list memory location may be determined by querying vector pointer table **1134**. A specific one type of waveform output from the list of available outputs is selected by control of a parameter of parameter table, typically stored in an address location corresponding to Communications Options (Heading A) type parameters described previously with reference to FIG. **7**B. Processor **900** at block **1116** stores the parameter table and the list of analog waveform outputs in a temporary storage device associated with processor **900** such as a RAM.

In the embodiment shown, the parameter table editing subprogram is configured by default to edit the existing parameter table stored in EROM of the connected reader if a reader is present. It will be recognized, however, that the editing subprogram can also be configured to query the user as to whether the user wishes to edit the parameter table currently stored in reader EROM **46**, or another candidate parameter table typically stored in a bulk storage device associated with processor **900**.

If a reader is not in communication with processor **900**, continuing with reference to the flow diagram shown, then processor at block **1168** prompts the user to select a reader for which the user wishes to edit a parameter table and once a type of reader is selected, a default parameter table associated with that reader type is written in to a temporary storage device of processor **900** typically provided by a RAM device.

At the termination of block **1168** or block **1166** if a reader is connected, a parameter configuration screen is displayed to a user, at block **1169**, an exemplary embodiment of which is shown in FIG. **11**E. Typically, a user will edit certain parameters from the parameter table which the user wishes to change, and then, when editing is complete, a user will select an available output option from the parameter configuration screen. The output options available to a user may include writing an edited parameter table to a connected reader; writing an edited parameter table to a bulk storage device; displaying an edited parameter table; or printing an edited parameter table.

Until an output option is selected, the user typically edits various parameters the user wishes to change as shown in blocks **1170** and **1172**. Selection of one parameter type option, e.g. code or symbology option parameter **1174** causes a secondary editing screen to appear allowing editing of parameters of the selected parameter type. When editing pertaining to one or several parameter types is complete then program reverts back to parameter configuration screen at block **1169**, allowing user to select an output option.

If a user selects the write output option (block **1176**), the edited parameter table is written to, or downloaded to reader EROM in the fashion described previously with reference to block **1140** of FIG. **11**B. If a user selects the store-to-disc option (block **1178**) then the edited parameter table is written to an address location of a bulk storage device such as a hard drive or floppy disc. If a user selects the display option (block **1180**) then processor **900** causes the complete or partial contents of the edited parameter table to be printed on display screen associated with host processor **900**. If a user selects the print option (block **1182**) then processor **900** causes the complete or partial contents of the edited parameter table to be printed by a printer device **940** in communication with processor **900**.

Another output option available to a user is to compare two or more parameter tables. If this option is selected (block **1184**) then the user is requested at block **1186** to select parameter tables from memory locations (which may be memory location associated with processor **900** or with reader **10**). When parameter tables have been selected, processor **900** at block **1186** compares the selected parameter tables. In general, the comparison is carried out by a compare function applied after an offset between the files is accounted for. Processor **900** then outputs the results of the comparison at block **1188**, typically by displaying the comparison results on screen **930**, or printing the comparison results using printer **940**.

One specialized output option of the invention allows the user to create programming menu symbols whose general features have described with reference to FIGS. **7**A through **7**C, and **8**. The menu symbols created by the output option can be used to reprogram readers reading the created symbols in accordance with the changes made to a parameter table made during execution of the parameter table subprogram. Described as a routine executed during a parameter table editing subprogram, the menu symbol output option can be conveniently implemented as a separate subprogram.

When a menu symbol output option is selected at block **1189**, processor **900** determines at block **1202**, by reading a reader identifier, whether the reader designated for receipt of the edited parameter table includes a one dimensional (1D) or two-dimensional (2D) image sensor.

If the reader includes a one dimensional image sensor, then processor **900** creates a series of linear bar codes which may be used for reprogramming several readers. Specifically, if the designated reader includes a one dimensional image sensor then processor **900** at block **1204** creates a first linear menu symbol adapted to generate an instruction causing the reader reading the symbol to change parameter table values of the reader's EROM to default values. Then, at block **1206** processor **900** creates a distinct linear programming menu symbol for each parameter of the parameter table that is changed during the editing process from a default value. An important feature of the invention is described with reference to block **1208**. When the series of menu symbols is created, the created symbols may be printed on paper by printer **940** according to a conventional protocol, or else displayed on display device **930**, typically a CRT monitor. The term created symbols herein refers to binary encoded data stored in a memory space which result in an actual symbol being output when the data is written to a display device or printer. An unlimited number of bar code readers may be reprogrammed by reading the menu symbols that are displayed on the display device **930**. Displaying the created menu symbols on a display device allows rapid output of created symbols and eliminates the need to supply a paper substrate each time a menu symbol is output.

If the reader designated for reprogramming includes a 2D image sensor, then processor **900** at block **1210** need only create one 2D menu symbol in order to cause reprogramming of the designated reader in accordance with the changes made to a parameter table even in the case where multiple changes to the parameter table are made. This is so because an increased number of instructions may be encoded in a symbol of a 2D symbology type.

Another subprogram which may be selected from a subprogram option screen displayed at block **1102** is a subprogram for simulating the result of applying editing commands to a decoded message. As discussed previously, editing commands may be applied to decoded messages by entry of the commands to a parameter table in parameter table addresses corresponding to heading H of FIG. **7**B. Without an editing command simulation subprogram, it would be necessary to decode a symbol with use of reader **10** in order to observe the result of applying the editing commands. The efficiency and convenience advantages of the editing command simulation subprogram therefore should be clear to those skilled in the art.

An exemplary flow diagram for an editing command simulation subprogram is shown in FIG. **11**E. At block **1214** processor **900** displays a message editing simulation screen or screens which allows a user to enter an unedited test message and symbology type (block **1216**) and enter the type of editing command desired to be applied to the message (block **1218**). Three basic types of editing commands are search and replace editing commands, insert character editing commands, and delete character editing commands. Additional, more complex editing commands may also be applied.

When the commands are entered, processor **900** applies the commands entered at block **1218** to the unedited test message at blocks **1220**, **1222**, and **1224** if all are applicable. When editing is complete processor **900** outputs the result of applying the editing commands, at block **1226**, typically by displaying the edited message on display screen **930**.

At block **1228** processor queries the user as to whether the user wishes to save the editing commands which resulted in the edited message being displayed or otherwise output at block **1226**. If the user elects to save the editing commands, then processor **900** at block **1230** writes the commands to a predetermined command save memory location associated with processor **900**. When the parameter table editing subprogram described with reference to FIG. **11**D is later executed the commands saved in block **1230** of the message editing command subprogram may be read from the command save memory location during execution of block **1192** of the parameter table editing subprogram.

In addition to being adapted to download new or modified operating programs to reader **10** remotely, processor **900** can also be adapted to remotely transmit component control instructions to reader **10** which are executed by reader processor **40** substantially on receipt by reader **10** to control one or more components of reader **10** in a manner that can be perceived by a reader operator. For example, processor **900** and reader **10** can be arranged so that processor **900**, on receipt of a command from a user, transmits a component control instruction to reader **10** which is executed by reader processor **40** to have the same effect as trigger **52** being manually pulled, or alternatively, being released. Instructions transmitted by processor **900** having the same effect as manually pulling and manually releasing trigger may be termed, respectively, "remote trigger activation" and "remote trigger release" instructions. Processor **900** and reader **10** can also be complementarily arranged so that, on receipt of a user activated command to remotely control reader **10**, processor **900** transmits to reader **10** an instruction which is executed by reader **10** substantially on receipt of the instruction to turn on LED's **22** or to "flash" LED's according to a predetermined pattern, or to activate an acoustic output device such as speaker **38** to issue a "beep" or a series of beeps. Component control instructions for on-receipt execution which operate to control LED's **22** or speaker **38** are useful, for example, to signal an alarm condition, to indicate that a task is completed, or to attract the attention of a reader operator for any purpose.

Processor **900** and reader **10** can also be complementarily arranged so that, on receipt of a user activated command, processor **900** transmits to reader **10** a component control instruction which is executed by reader **10** substantially on receipt thereof to transmit data which is stored in memory **45** or in another memory device associated with reader **10** such as a long-term nonvolatile memory device. For example, a component control instruction received from processor **900** may be executed by reader **10** to upload from reader **10** to processor **900** image data that is stored in a specific memory location of reader memory **45** such as a reader memory location that stores the most recently captured image data captured by reader. Processor **900** may subsequently display such uploaded image data on display **930**. Other component control instructions which may be transmitted from processor **900** to reader **10** for substantially on-receipt execution by reader processor **40** are instructions which, for example, cause predetermined indicia to be displayed by reader display **56**, or which cause processor **40** to capture, by appropriate control over image sensor **32**, a single frame of image data corresponding to the scene presently in the field of view of reader **10** in memory **45** or in another memory device.

It will be understood that certain component control instructions require that reader processor **40** execute a series of instruction steps, or repetitive instruction steps to cooperatively control more than one reader component. For example, a component control instruction commanding an optical reader to capture an image normally requires that processor **40** execute a series of instruction steps involving control of such components as LED's **22**, components of the imaging assembly, and memory **45**.

A modified reader operating program that adapts a reader to receive component control instructions from a remote local host processor for substantially on-receipt execution by reader **10** is shown in FIG. **6**B. Reader **10** is readily enabled to receive and execute remote component control instructions by modification of the program loop indicated by block **605** of FIG. **6**A wherein reader **10** waits in a low power state until a trigger is pulled. As shown by the flow diagram of FIG. **6**B, block **605** may be modified to the form illustrated by block **605'** so that reader executes block **610** and the ensuing blocks shown and described in connection with FIG. **6**A in response either to a trigger being manually pulled or to the receipt of a remote trigger activation instruction from processor **900**. Block **635** of the flow diagram of FIG. **6**A may also be modified so that the reader is responsive either to a manual trigger release or to receipt of a remote trigger receive instruction. Reader **10** may also be made to exit the loop indicated by block **605'** on the condition that another component control instruction for on-receipt execution by reader **10** is received. As is indicated by block **602** and block **603**, reader **10** may be adapted to exit the loop indicated by block **605'** and to appropriately control the component associated with the received instruction on the condition that a remote component control instruction is received from processor **900**.

Scanning-Decoding/Autodiscrimination

The scanning-decoding and autodiscrimination features of the invention, and their relationships to the above-described menuing and reprogramming features, will now be described with reference to FIGS. **6** and **12**–**18**. More particularly, the combined operation of these features will be discussed in connection with FIG. **6**A. The SOD, SS and DOD scanning-decoding modes of the invention will be discussed in connec-

tion with FIGS. **13** and **14**, and the OS, RUD and RUS scanning-decoding modes of the invention will be discussed in connection with FIG. **15**. Finally, the 1D and 2D portions of the autodiscrimination feature of the invention will be discussed in connection with FIGS. **16**–**18**, respectively.

Turning first to the main program of FIG. **6**A, the scanning and decoding operations are shown as blocks **625**–**647**. In those embodiments or modes in which the multiple symbols code option is not enabled (see option B**5** of FIG. **7**B), the processor assumes, that only one symbol is to be decoded. Under this condition, if decoding is successful, the processor processes the decoded symbol as a menu symbol in accordance with previously described menu routine **660**, or as output data in accordance with block **646**, and then is stopped by one of blocks **647**, **635** or **642**. If decoding is not successful, the processor is directed back (unless stopped by blocks **635** or **642**) to capture and attempt to decode another image. In this case, the "no" output of multiple symbols block **643** is selected, allowing additional images to be captured as necessary.

In those embodiments or modes in which the multiple symbols option is enabled, the processor assumes that more than one symbol is present in the image data. Under this condition, if decoding is successful, the processor continues to loop back to block **627** to make additional decoding attempts, unless stopped by one of blocks **635** or **642**. In this case, however, the "yes" output of block **643** is selected, preventing additional images from being captured.

When the processor begins executing its scanning-decoding program, it first determines from the parameter table which scanning-decoding option or combination of options is to be used. It will then be directed to an autodiscrimination routine that is configured to execute that routine in accordance with the selected scanning-decoding option or options.

At start up, the parameter table may be set up so that operation in the One Shot scanning-decoding mode is established as a default condition. Alternatively, the parameter table may be set up so that the RUD or RUS scanning-decoding mode is established as a default condition. Since the One Shot mode is inherently a non-tracking mode, its selection as a default mode implies that none of the tracking modes is selected. Since the RUD and RUS modes can be used either with or without one of the three tracking modes, its selection as a default parameter may or may not be associated with one of the three tracking modes, depending upon how the reader is programmed at the time of manufacture.

(a) Tracking Options

The differences between the three tracking modes of the invention are best understood with reference to FIGS. **12**–**14**. The latter figures (with changes in figure and indicia number) are incorporated from prior copending U.S. patent application Ser. No. 08/914,883 (now U.S. Pat. No. 5,942,741), together with their associated descriptions as follows:

Scanning of indicia can take place under either of two generalized conditions, depending upon the decoding load presented by the indicia. Under light decoding loads, shown in FIG. **12**A for a prior art reader, the amount of data to be decoded is relatively small, allowing scan data from a complete scan to be decoded in a time which is less than the duration of a scan. Under this condition, the result of each scan is decoded before the completion of the following scan, and no problems arise as a result of any mismatch between the scan time and the decode time of the reader. The prior art and the instant invention perform equally well under such light decoding loads as will be seen later from FIG. **13**.

Under heavy decoding loads, however, prior art methods do not allow sufficient time for decoding. Thus, as shown in FIG. **12**B, when a first scan, Scan **1** is completed, a second scan, Scan **2** is initiated immediately. Scan **2** is then followed by Scan **3** while the decoding of Scan **1** is still in progress. As this situation continues, the decoding process will be seen to fall further and further behind the scanning process until, at some point, the data memory becomes filled. When this occurs new scan data will overwrite old scan data which was not processed, thereby causing a loss of large blocks of scan data.

In the embodiment of the invention disclosed in prior copending application Ser. No. 08/205,539, now issued as U.S. Pat. No. 5,463,214, this problem is solved by modifying the reader in a way that allows the scanning process to be suspended and restarted as required to prevent the decoding process from falling so far behind the scanning process that data overflows the memory and is lost. This embodiment is referred to herein as the "Scan on Demand" or SOD tracking mode. This solution to the problem may be understood with reference to FIGS. **13**A and **13**B. Referring to FIG. **13**A, there is shown the operation of the subject embodiment of the invention under light decoding loads. It will be noted that, under this condition, the relationship between scanning and decoding is the same as that shown in FIG. **12**A.

FIG. **13**B shows the relationship which exists between the scanning and decoding processes when the Scan On Demand mode of the invention is used under heavy decoding loads. As shown in FIG. **13**B, the suspension of the scanning process continues until the results of the prior scan have been decoded. This prevents the decoding process from falling more than a small amount of time behind the scanning process. As a result, there cannot arise a situation, such as that which can arise with the prior art, in which there is a massive loss of scan data. Because this process is described in detail in U.S. Pat. No. 5,463,214, it will not be described in detail herein.

Referring to FIG. **13**C there is shown the tracking relationship which exists between the scanning and decoding operations when these operations are controlled in accordance with a tracking mode referred to as the "Skip Scan" or SS tracking mode. With this mode, under heavy decoding loads, decoding proceeds without interruption so long as the scanning function is called for. As shown in FIG. **13**C, each decoding operation begins immediately after the preceding decoding operation ends, and proceeds on the basis of the scan data from the then most current complete block of scan data.

More particularly, FIG. **13**C illustrates one possible scenario in which decoding of Scan **1** data is immediately followed by the decoding of Scan **2** data. This occurs because Scan **3** data is incomplete at the time that the second decoding operation begins. The decoding of Scan **2** data, however, is immediately followed by the decoding of Scan **5** data. This occurs because Scan **5** data represents the then most current complete block of scan data. While the results of scans **3** and **4** are therefore unused and skipped over, the data lost by their non-use is provided by more current scan data or, if decoding is unsuccessful, by the results of a later scan. Any occasional decoding failure that results from the skipping of relatively old blocks of scan data is in any case more than offset by the avoidance of the large scale data losses discussed in connection with FIG. **12**B.

Referring to FIG. **13**D there is shown the tracking relationship which preferably exists between the scanning and decoding operations when these operations are performed in a reader which includes two and only two scan data memory spaces A and B. With this reader, the preferred tracking mode

is the "Decode on Demand" or DOD tracking mode. With this mode decoding does not proceed without interruption. As shown in FIG. **13**D, each decoding operation begins at the beginning of a block of scan data. In the event that the end of a decoding operation does not coincide with the beginning of such a block, i.e., occurs while a scanning operation is still in progress, the beginning of the next decoding operation will be delayed until the scanning operation that is then in progress is completed, and then proceeds with reference to the block of scan data which is produced by that scanning operation.

More particularly, FIG. **13**D shows that the decoding of Scan **1** data is completed while Scan **3** is still in progress, overwriting data for Scan **2**. Under this condition, decoding is discontinued for a time period T_{s1} that is equal to the time necessary for Scan **3** to be completed. At the end of time period T_{s1}, decoding resumes with the then most current block of scan data, namely: the scan data produced during Scan **3**. Thus, like the mode which is illustrated FIG. **13**C, the mode which is illustrated in FIG. **13**D begins its decoding operation with the then most current complete block of scan data.

Referring to FIG. **13**E, there is shown the tracking relationship which exists between the scanning and decoding operations when these operations are performed in a reader which includes three scan data memory spaces A, B and C. With this embodiment decoding proceeds without interruption so long as the scanning function is called for. As shown in FIG. **13**E, each decoding operation begins immediately after the preceding decoding operation ends, and proceeds on the basis of scan data from the memory which contains the then most current complete block of scan data.

More particularly, FIG. **13**E shows that the decoding of Scan **1** is completed while Scan **3** is still being acquired. Under this condition, with three memory spaces available, decoding is immediately undertaken on the most recent complete Scan (Scan **2**) which is contained in memory space B. Upon the completion of the decoding of Scan **2**, decoding is commenced on Scan **4** which is contained in memory space A. Thus, the utilization of three memory spaces allows the decoding portion of the invention to be occupied one hundred percent of the time.

The mode illustrated in FIG. **13**C is best suited for use with readers having memories and addressing procedures which can accommodate large numbers of relatively short blocks of scan data having sizes that are not known in advance. Applications of this type typically include readers, such as that shown in FIG. **3**, which use 1D image sensors.

The modes illustrated in FIGS. **13**D and **13**E, on the other hand, are best suited for use with readers having memories and addressing procedures which can accommodate small numbers of relatively long blocks of scan data of fixed length. Applications of these types typically include readers, such as that shown in FIG. **2**, which use 2D image sensors. With the embodiment illustrated in FIG. **13**D, only two scan data memory spaces are used and decoding is discontinuous. With the embodiment illustrated in FIG. **13**E three scan data memory spaces are used and decoding is continuous. More than three scan data memory spaces can also be used if additional decoding resources are made available. The one of these different embodiments which is used in a particular application is a design choice which is based on economic considerations.

The fact that some embodiments of the invention use 1D image sensors while others use 2D image sensors should not be taken to mean that embodiments which use 1D image sensors can only read 1D symbols or that embodiments which use 2D image sensors can only read 2D symbols. This is because techniques exist for using either type of image sensor to read both 1D and 2D symbols. It will therefore be understood that the present invention is not restricted to use with any one type of image sensor or to any one type of bar code or other optically encoded symbol.

Referring to FIG. **14**A, there is shown a memory space M**1** suitable for use in storing blocks of scan data of the type produced by a reader with a 1D image sensor, together with a pointer or tracking memory M**2** suitable for use in storing address or pointer information that makes it possible for the reader to identify the beginning and end point of a block of interest. As shown in FIG. **14**A, the block of scan data produced during a first scan of the target is stored in memory M**1** beginning at address SS**1** (Scan Start for Scan **1**) and ending at address SE**1** (Scan End for Scan **1**). Similarly, the block of scan data resulting from a second scan of the target is stored between addresses SS**2** and SE**2**, and so on. Because scanning takes place continuously, the end of one scan block (e.g. SE**1**) coincides with the beginning of the next scan block (e.g., SS**2**). The sizes (in memory space) of these blocks will ordinarily vary from block to block, depending on the number of data transitions in each 1D scan of the target. The boundaries between blocks will, however, be fixed by the occurrence times of the Scan Interrupt signals which are generated by the image sensor or its clock generating circuitry.

Locations SS and SE of memory M**2** are updated in the course of a series of scans so that they always identify or otherwise point to the address of the beginning and ending of the most recently produced complete block of scan data. As a result, when the decoding circuitry is ready to decode the most recently produced complete block of scan data, it need only refer to locations SS and SE to obtain information as to where to begin and end decoding. Before decoding begins, the contents of locations SS and SE are written into locations DS (Decode Start) and DE (Decode End) so that locations SS and SE can continue to be updated while decoding proceeds on the basis of the contents of locations DS and DE. In the preferred embodiment, the decoding circuitry is programmed to mark these beginning addresses as "invalid" (for example, by changing its sign) after it is acquired. Since the decoding processor is programmed to decode only "valid" data, this assures that it can decode a single block of scan data only once.

Referring to FIG. **14**B there are shown a plurality of memory spaces MA, MB . . . MN suitable for use in storing blocks of scan data of the type produced by a reader having a 2D image sensor, together with a pointer or tracking memory MP suitable for use in storing address or pointer information for identifying the memory spaces to be used for entering new scan data, decoding, etc. Since the amount of scan data in each block of scan data is known in advance, being the same for each scan, the starting and ending addresses for each memory space (e.g., A_1 and B_1 and A_N and B_N, etc.) will also be the same for each scan. As a result, the memory to be used for storing new scan data, decoding etc. may be specified by specifying just a few bits stored in memory MP. Location CS, for example, may be used as a pointer which identifies the memory where the current scan is being stored, and location NS may be used as a pointer which identifies where the next scanned image is to be stored.

Similarly, location CD may be used as a pointer which identifies the memory space where the current decode is being undertaken. Finally, location ND may be used as a pointer which identifies where the next available image is for decoding purposes.

Under ordinary circumstances, three scan data memory spaces will be sufficient to keep the decoding activity of the

reader fully occupied and current. This is because the tracking method of the invention allows the skipping over of old blocks of scan data as necessary for the decoder to remain occupied and current. If the decoding load becomes extremely heavy, however, it is possible that more old blocks of scan data are skipped over than is advisable. In such instances, it may be desirable to increase the number of memory spaces from 3 to N, where N may be 4 or even more, and to use more than one decoding circuit. If such an increased number of memories and decoders is used, blocks of scan data may be distributed among the memories according to a simple sequential rule and kept track of by increasing the number of bits in the pointers of memory space MP. In addition, the decoding circuits may be assigned to the then most current complete block of scan data as they become free. It will be understood that all such numbers of memory spaces and decoding circuits and the associated tracking procedure are within the contemplation of the present invention.

Referring to FIG. **15**, there is shown a simplified version of FIG. **6**A which eliminates those blocks which do not relate directly to the use of the scanning-decoding parameters of FIG. **7**B to produce decoded output data. Of the blocks shown in FIG. **15**, blocks **625**, **627** and **646** are common to prior art readers and to readers constructed according to the present invention. The remaining blocks of FIG. **15** operate either singly or in various combinations to establish the permitted combinations of the scanning-decoding modes shown in FIG. **7**B. These remaining blocks together comprise the preferred embodiment of the means by which the reader of the invention is controlled in accordance with the scanning-decoding relationships called for by the parameter table thereof. Other combinations of flow chart blocks, and other combinations of scanning-decoding parameters may also be used, however, without departing from the present invention. Blocks **642** and **643** may, for example, be configured so that only a preset number of multiple symbols or a preset number of repeats is permitted. Alternatively, all scanning-decoding control blocks may be collectively replaced by a look-up table which directly specifies the next action to be taken. These and other variants will be understood to be within the contemplation of the present invention.

In view of the foregoing, it will be seen that the scanning and decoding processes of the invention may have a selectable one of any of a plurality of different relationships with one another, some of these relationships being tracking relationships and some being non-tracking relationships. In accordance with the invention, the menuing feature of the invention allows a user to select that operating mode, whether or not tracking, which gives the best overall data throughput rate in view of the user's then current objectives.

(b) Autodiscrimination/Code Options

The manner in which the code options called for by the parameter table of the invention are implemented in conjunction with the autodiscrimination feature of the invention, will now be described with reference to the flow charts of FIGS. **16** and **18**. Generally speaking, the flow chart of FIG. **16** illustrates the 1D portion of a complete 1D/2D autodiscrimination process, while the flow chart of FIG. **18** illustrates the 2D portion of a complete 1D/2D autodiscrimination process. If both the 1D and 2D code options of the parameter table are enabled (see options B**1** and B**2** of FIG. **7**B), the steps called for by both FIGS. **16** and **18** will be executed before the autodiscrimination process is completed. If, however, only one or the other of the 1D and 2D code options of the parameter table is enabled, only the steps called for by FIG. **16** or by FIG. **18** will be executed before the autodiscrimination process is completed. It will therefore be seen that the menuing features and the autodiscrimination features of the present invention interact with one another in a manner that allows a user to tailor the autodiscrimination circuitry as necessary to achieve the highest possible data throughput rate for a particular application.

In order to gain an understanding of the present invention as a whole, it should be borne in mind that the above-described relationships between the decoding and menuing processes of the invention exist as a subset of an even more complex set of relationships that include the tracking and multiple symbols features of the invention. When, for example, a portion of the flow chart of FIGS. **16** and **18** calls for an attempted decode, it must be remembered that the attempted decode takes place in the context of the tracking or non-tracking relationships indicated by the parameter table options. In addition, the number of passes that the processor makes through the flow chart of FIG. **16**, before continuing on to the flow chart of FIG. **18**, depends upon whether or not the multiple symbols feature of the invention has been enabled.

In principle, at least, each one of the possible combinations of the above-described options may be represented in a complete and separate flow chart and described as such. Because adopting the latter approach would obscure rather than clarify the present invention, however, the present application will describe these combinations simultaneously in terms of a representative flow chart, with different options being described potential variants of that representative flow chart.

Turning first to the flow chart of FIG. **16**, there is shown the 1D portion of the autodiscrimination process, which operates on a set of image data that has been scanned from a target symbol of unknown type and orientation and stored in RAM **45**. If the reader is a 2D reader, this image data will comprise a gray scale representation of the 2D image formed on the image sensor, each pixel of the image sensor being represented by an image data element that includes an 8 bit gray scale indication of its brightness. If, on the other hand, the reader is a 1D reader, the image data may comprise either binary or gray scale values.

If the reader includes a 2D image sensor, this image data will have been scanned as a 2D image while the reader is held substantially stationary with respect to its target. If the reader includes a 1D image sensor this image data will have been scanned as a series of 1D images while the reader is being moved asynchronously across the target in the manner described in copending commonly assigned U.S. patent application Ser. No. 08/504,643 (now U.S. Pat. No. 5,773,806), which is expressly incorporated herein by reference.

On encountering block **1605**, the processor is directed to calculate the "activities" of selected image data elements. The "activity" of a point P as used herein comprises a measure of the rate of change of the image data over a small two dimensional portion of the region surrounding point P. This activity is preferably calculated along any two arbitrarily selected directions which are mutually perpendicular to one another, as shown by the lines parallel to directions X and Y of FIG. **17**A. One example of an activity calculation is that which is based on the squares of the gray scale differences of two pairs of points P**1**X-P**2**X and P**1**Y-P**2**Y that are centered on point P, as shown in FIG. **17**A. Two mutually perpendicular directions are used because the orientation of the symbol is unknown and because a high activity level that by chance is difficult to detect in a first direction will be readily detectable in a second direction perpendicular to that first direction.

In the preferred embodiment, an activity profile of the image data is constructed on the basis of only a selected,

relatively small number of image data elements that are distributed across the field of view that corresponds to the stored image data. Using a relatively small number of data elements is desirable to increase the speed at which the symbol may be imaged. These selected points may be selected as the points which lie at the intersections of an X-Y sampling grid such as that shown in FIG. **17**A. The spacing of the lines defining this grid is not critical to the present invention, but does affect the resolution with which the activity profile of the image can be measured.

When the processor has determined the activities of the selected image data points, it is directed to block **1610**, which causes it to look for candidate bar code symbols by identifying regions of high activity. This is conveniently done by determining which sets of image data points have activities that exceed a predetermined activity threshold value. A simplified, one-dimensional representation of this step is illustrated in FIG. **17**B, wherein those image data points having an activity that exceed a threshold value TH are labeled as a candidate symbol region CSR**1**.

In embodiments which are adapted to find and decode all of the symbols that occur in fields of view that include a plurality of bar code symbols, (i.e., embodiments in which the multiple symbols option is enabled), the result of the step called for by block **1610** is the identification of a plurality of candidate symbol regions (CSRs), any one or more of which may be a bar code symbol. Whether or not they are bar code symbols is determined on the basis of whether they are decodable. As will be explained more fully later, if the multiple symbols option is not enabled, the processor may be instructed to select one of the CSRs according to a suitable selection rule, such as the largest CSR first, the CSR nearest the center of the field of view first, the CSR with the highest total activity first, etc., and then attempt to decode only that symbol and stop, whether or not a symbol has been decoded. Alternatively, as a further option, the processor may be instructed to attempt to decode each CSR in turn until one of them is successfully decoded, and then stop. If the multiple symbols option is enabled, the processor will process all of the CSRs, in turn, according to a suitable priority rule, and continue to do so until all of the CSRs have been either decoded or have been determined to be undecodable.

Once all CSRs have been located, the processor is directed to block **1615**, which calls for it to select the then largest (or most centrally located) as yet unexamined CSR for further processing, and then proceed to block **1620**. The latter block then causes the processor to find the centroid or center of gravity of that CSR, before proceeding to block **1625**. An example of such a centroid is labeled C in FIG. **17**C. Because the steps involved in finding a centroid are well known, they will not be described in detail herein.

On encountering block **1625**, the processor is directed to examine the selected CSR by defining various exploratory scan lines therethrough, determining the activity profile of the CSR along those scan lines, and selecting the scan line having the highest total activity. In the case of a 1D bar code symbol, this will be the direction most nearly perpendicular to the direction of the bars, i.e., the optimum reading direction for a 1D symbol.

On exiting block **1625**, the processor encounters blocks **1630** and **1635**. The first of these sets a scan line counter to zero; the second defines an initial, working scan line through the centroid in the previously determined direction of highest activity. The result of this operation is the definition, in the image data space representation of the CSR, of a working scan line such as SC=0 in FIG. **17**C.

Once the initial scan line has been defined, the processor is directed by block **1640** to calculate, by interpolation from the image data of the CSR, the values of sampling points that lie along this scan line. This means that, for each sampling point on the initial scan line, the processor will calculate what brightness the sampling point would have if its brightness were calculated on the basis of the weighted brightness contributions of the four nearest measured image data points of the CSR. These contributions are illustrated by the dotted lines which join the sample point SP of FIG. **17**D to the four nearest image data points DPA-DPD. So long as these sampling points are more closely spaced than the image data points, this interpolation procedure will be performed on a subpixel basis, and will produce a usably accurate representation of the image data along the scan line. The result of the subpixel interpolation of the sampling points on a representative scan line of this type is shown in FIG. **17**E. Because the particulars of the subpixel interpolation process are known to those skilled in the art, this process will not be further described herein.

Once the above-described scan line data have been calculated, the processor is directed to block **1645**, which calls for it to binarize the scan line data, i.e., convert it to a two-state representation of the data which can be processed as a candidate for 1D decoding. One such representation is commonly known as a timercount representation. One particularly advantageous procedure for accomplishing this binarization process is disclosed in U.S. Pat. No. 5,286,960, which is hereby incorporated herein by reference.

On exiting block **1645**, the processor will be in possession of a potentially decodable two-state 1D representation of the CSR. It then attempts to decode this representation, as called for by block **1650**. This attempted decoding will comprise the trial application to the representation of one 1D decoding program after another until the latter is either decoded or determined to be undecodable. Because decoding procedures of the latter type are known to those skilled in the art, they will not be discussed in detail herein.

As the 1D autodiscrimination process is completed, the processor is directed to decision block **1655** which causes it to continue along one of two different paths, depending on whether or not decoding was successful. If it was not successful, the processor will be caused to loop back to block **1635**, via blocks **1660** and **1665**, where it will be caused to generate a new working scan line that is parallel to initial scan line SC=**0**, but that passes above or below centroid C. This looping back step may be repeated many times, depending on the "spacing" of the new scan lines, until the entire CSR has been examined for decodable 1D data. If the entire CSR has been scanned and there has been no successful decode, the processor is directed to exit the just-described loop via block **1670**. As used herein, the term "parallel" is used in its broad sense to refer to scan lines or paths which are similarly distorted (e.g., curvilinear) as a result of foreshortening effects or as a result of being imaged from a non-planar surface. Since compensating for such distorting effects is known, as indicated, for example, by U.S. Pat. No. 5,396,054, it will not be discussed in detail herein.

Block **1670** serves to direct the processor back to block **1615** to repeat the above-described selection, scanning and binarizing steps for the next unexamined CSR, if one is present. If another CSR is not present, or if the processor's program calls for an attempt to decode only one CSR, block **1670** causes the processor to exit the flow chart of FIG. **16** to begin an attempt to decode the then current set of image data as a 2D symbol, in accordance with the flow chart of FIG. **18**. If other CSRs are present, and the multiple symbols option is

enabled, block **1670** directs the processor back to block **1615** to repeat the selection, scanning and binarizing process for the next CSR, and the next, and so on, until there is either a successful decode (block **1655**) or all of the CSRs have been examined (block **1670**).

If the processing of the first CSR has resulted in a successful decode, block **1655** directs the processor to block **1675**, which causes it to determine whether the decoded data indicates that the CSR contains a 1D stacked symbol, such as a PDF417 symbol. One example of such a symbol is shown in FIG. **19**D. If it is not, i.e., if the decoded symbol includes only a single row of bars, the 1D data is stored for later outputting in accordance with block **648** of the main program of FIG. **6**A, as called for by block **1680**. Alternatively, the data may be output immediately and block **648** later skipped over. Then, if there are no remaining unexamined CSRs, or if the multiple symbols option is not enabled, the processor is directed to exit the flow chart of FIG. **16** via block **1682**. If, however, there are remaining CSRs and the multiple symbols option is enabled, block **1682** will direct the processor back to block **1615** to begin processing the next CSR, and the next, and so on until all CSRs have been examined and decoded (block **1682**) or examined and found to be undecodable (block **1670**).

If, on encountering block **1675**, the decoded data indicates that the CSR contains a 1D stacked symbol, the above-described processing is modified by providing for the repetition of the scanning-digitizing process, beginning with block **1635**. This is accomplished by blocks **1684**, **1686** and **1688** in a manner that will be apparent to those skilled in the art. Significantly, by beginning the repeating of the process at block **1635**, all additional scan lines defined via the latter path will be parallel to the first decodable scan line, as required by a 1D stacked symbol, at least in the broad sense discussed earlier.

In view of the foregoing, it will be seen that, depending on the number of CSRs that have been found in the stored image data, and on the enablement of the multiple symbols option, the flow chart of the embodiment of the invention shown in FIG. **16** will cause all 1D symbols in the image data to be either decoded or found to be undecodable before directing the processor to exit the same.

As will be explained more fully in connection with FIG. **20**, the 2D autodiscrimination flow chart of FIG. **18** may be processed after the processing of the 1D autodiscrimination flow chart of FIG. **16** has been completed. It may also be processed without the flow chart of FIG. **16** having been previously processed, i.e., the 1D portion of the 1D/2D autodiscrimination process may be skipped or bypassed. (In principle, the steps of the 2D portion of the 1D/2D autodiscrimination process (FIG. **18**) may also be processed before the 1D portion thereof (FIG. **16**), although this option does not comprise the preferred embodiment of the invention.) This is because the code options of the menuing feature of the invention make all of these options selectable by the user. It will therefore be understood that the present invention contemplates all possible combinations of autodiscrimination options.

Referring to FIG. **18**, there is shown a flow chart of the 2D portion of the 1D/2D autodiscrimination process of the invention. When the flow chart of FIG. **18** is entered, the image data that is stored in RAM **45** is the same as that which would be stored therein if the flow chart of FIG. **16** were being entered. If the reader is a 2D reader this image data will comprise an array of 8-bit gray scale image data elements produced by image sensor **32-2** and its associated signal processing and A/D converter circuits **3502** and **36-2**. If the reader is a 1D reader that produces a 2D image by being moved across the target symbol, the image data will comprise an array of binary data elements such as those shown in above-cited copending application Ser. No. 08/504,643.

The flow chart of FIG. **18** begins with a block **1805**, which directs the processor to convert the gray scale image data representation stored in RAM **45** (if present) into a two-state or binarized representation of the same data. This may be accomplished in generally the same manner described earlier in connection with FIG. **17**B, i.e., by comparing these gray scale values to a threshold value and categorizing these values as is or Os, depending upon whether they exceed or do not exceed that threshold value.

Once the image data has been binarized, the processor continues on to block **1810**, which causes it to identify and locate all of the 2D finder patterns that appear in the field of view of the image data. This is preferably accomplished by examining all of the candidate 2D finder patterns (CFPs) that are present and identifying them by type, i.e., identifying whether they are bullseye type finder patterns, waistband type finder patterns or peripheral type finder patterns. An example of a bullseye type finder pattern is shown in the central portion of the 2D bar code symbol of FIG. **19**A, which symbol encodes data in accordance with a 2D matrix symbology named "Aztec". An example of a waistband type finder pattern is shown in the middle portion of the 2D bar code symbol of FIG. **19**B, which symbol encodes data in accordance with a 2D matrix symbology named "Code One". An example of a peripheral type finder pattern is shown in the left and lower edges of the 2D bar code symbol of FIG. **19**C, which symbol encodes data in accordance with a 2D matrix symbology known as "Data Matrix". The finder identification process is performed by applying to each CFP, in turn, a series of finder pattern finding algorithms of the type associated with each of the major types of finder patterns. Since such finder finding algorithms are known for finders of the waistband and peripheral types, these algorithms will not be discussed in detail herein. One example of a finder finding algorithm for a waistband type finder, may be found, for example, in "Uniform Symbology Specification Code One", published by AIM/USA Technology Group. Finder finding algorithms for bullseye type finders that include concentric rings, (e.g. MaxiCode) are also known and will also not be described in detail herein.

Particularly advantageous for purposes of the present invention, however, is bullseye type finder finding algorithm of the type that may be used both with 2D symbologies, such as MaxiCode, that have bullseye finder patterns that include concentric rings and with 2D symbologies, such as Aztec, that have bullseye finder patterns that include concentric polygons. A finder finding algorithm of the latter type is described in copending, commonly assigned U.S. patent application Ser. No. 08/504,643 (now U.S. Pat. No. 5,773,806), which has been incorporated herein by reference. The Aztec 2D bar code symbology itself is fully described in U.S. patent application Ser. No. 08/441,446 (now U.S. Pat. No. 5,591,956), which has also been incorporated herein by reference.

Once all of the finder patterns have been located and their types have been determined, the processor is directed to decision block **1815**. This block affords the processor an opportunity to exit the flow chart of FIG. **18**, via exit block **1820**, if no 2D finder patterns could be found and typed. This block speeds up the execution of the program by skipping over decoding operations which have no hope of success without their associated finder pattern.

If a finder pattern has been found and typed, the processor is directed to block **1825**. This block causes the processor to select for decoding the bar code symbol whose finder is

closest to the center of the field of view of the image data. Optionally, the processor may be instructed to find the largest 2D bar code symbol that uses a particular 2D symbology or the 2D bar code symbol using a particular 2D symbology which is closest to the center of the field of view of the image data. The "closest-to-the-center" option is ordinarily preferred since a centrally located symbol is likely to be a symbol, such as a menu symbol, at which the user is deliberately aiming the reader. Once this selection has been made, the processor attempts to decode that symbol, as called for by block **1830**. If this decoding attempt is successful, as determined by decision block **1835**, the resulting data may be stored for outputting in accordance with block **648** of the main program of FIG. **6**A, as called for by block **1840**. Alternatively, the decoded data may be output immediately and block **648** later skipped over. If the decoding attempt is not successful, however, block **1840** is skipped, and the processor is directed to decision block **1845**.

If the user has elected not to use the multiple symbols option, block **1845** may direct the processor to exit the flow chart of FIG. **18**, via block **1850**, after any 2D symbol has been successfully decoded. Optionally, block **1845** may be arranged to direct the processor to exit the flow chart of FIG. **18** after the attempted decoding of the centermost symbol, without regard to whether or not the decoding attempt was successful.

If the user has elected to use the multiple symbols option, block **1845** will direct the processor back to block **1825** to process the next 2D symbol, i.e., the symbol whose CFR is next closest to the center of the field of view. The above-described attempted decoding and storing (or outputting) steps will then be repeated, one CFR after another, until there are no more symbols which have usable finder patterns. Finally, when all symbols having usable finder patterns have been either decoded or found to be undecodable, the processor will exit the flow chart of FIG. **18**, via block **1850**, to return to the main program of FIG. **6**A.

In view of the foregoing, it will be seen that, depending on the number of identifiable CFRs that have been found in the stored, digitized image, and on the enablement of the multiple symbols option, the 2D autodiscrimination routine shown in FIG. **18**, will cause one or more 2D symbols in the image data to be either decoded or found to be undecodable before directing the processor to exit the same.

For the sake of clarity, the foregoing descriptions of the 1D and 2D phases of the 1D/2D autodiscrimination process of the invention have been described separately, without discussing the combined or overall effect of the code options and scanning-decoding options discussed earlier in connection with FIG. **7**B. The overall effect of these code options and the manner in which they are implemented will now be described in connection with FIG. **20**. As will be explained presently, FIG. **20** shows (with minor simplifications) the contents of block **627** of FIG. **6**A. It also shows, as blocks **2010** and **2035** (again with minor simplifications), the 1D and 2D autodiscrimination routines discussed earlier in connection with FIGS. **16** and **18**, respectively.

On entering the flow chart of FIG. **20**, the processor encounters a block **2005** which causes it to determine, with reference to the code options of the parameter table, whether all of the 1D codes have been disabled. If they have not, the processor continues to block **2010**. In accordance with block **2010**, the processor performs the 1D autodiscrimination process described in connection with FIG. **16**, using the 1D code and scanning-decoding options indicated by the parameter table. Depending upon whether 1D decoding was successful, as determined by block **2015**, the processor either outputs (or stores) data per block **2020** and exits, or continues on to blocks **2030** and **2035** to begin the 2D autodiscrimination process.

If all 1D codes have been disabled, the processor is directed directly to block **230**, thereby skipping block **2010** in its entirety. Then, unless all 2D codes have also been disabled (per block **2030**), it proceeds to block **2035** to begin the autodiscrimination process described in connection with FIG. **18**, using the 2D codes and scanning-decoding options indicated by the parameter table. Depending upon whether 2D decoding was successful, as determined by block **2040**, the processor either outputs (or stores) data, per block **2045**, or returns to the main program of FIG. **6**A. Returning to the latter then causes or does not cause further scans to be made depending on the states of blocks **635** and **640** thereof.

In view of the foregoing, it will be seen that the 1D/2D autodiscrimination process of the invention may be practiced in many different ways, depending upon the menuing options that have been chosen by the user. Among these menuing options, the code options increase the data throughput rate of the reader by assuring that the processor does not waste time trying to autodiscriminate and decode symbols which it has been told are not present, or are not of interest. The scan tracking options also increase the data throughput rate of the reader by assuring that the scanning and decoding phases of read operations both operate, to the extent possible in view of the then current decoding load and decoding options, at a 100% utilization rate. Even the multiple symbols option also increases the data throughput rate of the reader by either discontinuing the reading of symbols that are not centered and therefore not of interest or speeding up the processing of multiple symbols that are of interest. Thus, for a processor with a given performance rating and a set of decoding programs of given length, the apparatus of the invention assures a higher overall data throughput rate than has heretofore been possible.

While the present invention has necessarily been described with reference to a number of specific embodiments, it will be understood that the time spirit and scope of the present invention should be determined only with reference to the following claims.

What is claimed is:

1. A system comprising:

(a) an optical reader including an imaging assembly, a display, a keyboard, an acoustic output device and a controller configured to capture image data and decode decodable bar code symbols therein, said optical reader further including a hand held housing encapsulating said imaging assembly and said controller, said hand held housing further supporting said display and said keyboard; and

(b) a host processor having an associated display spaced apart from said optical reader, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is configured so that in a first mode said host processor sends to said optical reader a beeper control instruction, wherein said optical reader substantially on receipt of said beeper control instruction actuates said acoustic output device so that said acoustic output device emits a series of beeps without actuating said display;

(d) wherein said system is further configured so that in a second mode said host processor sends to said optical reader a display control instruction, wherein said optical

reader substantially on receipt of said display control instruction causes a predetermined indicia to be displayed on said display without actuating said acoustic output device.

2. The system of claim **1**, wherein said optical reader further includes a light source, and wherein said system is configured so that said host processor in a further mode sends to said optical reader a light source control instruction, said optical reader substantially on receipt of said light source instruction causes said light source to flash on and off.

3. The system of claim **1**, wherein said acoustic output device is a speaker.

4. The system of claim **1**, wherein said imaging assembly includes a two dimensional solid state image sensor.

5. The system of claim **1**, wherein said display is provided by a liquid crystal display.

6. A method for attracting attention of an operator of a hand held optical reader, said hand held optical reader having an artificial light source directing light toward a target, an acoustic output device, a wireless communication link, a display, and being configured to decode decodable bar code symbols represented in captured images, said method comprising the steps of:

(a) configuring said hand held optical reader to wirelessly receive at least one component control instruction from a spaced apart host processor, said component control instruction being selected from the group consisting of a light source flashing component control instruction which when executed by said hand held optical reader results in artificial light from said artificial light source being directed toward a target of said optical reader without a frame of image data being captured, an acoustic output device component control instruction which when executed by said hand held optical reader causes said acoustic output device to emit a series of beeps without actuation of said display, and a display output component control instruction which when executed by said hand held optical reader results in a predetermined indicia being displayed on said display without actuation of said acoustic output device, wherein said configuring step includes the step of configuring said hand held optical reader to execute said at least one component control instruction to produce a user-perceivable result substantially on receipt of said component control instruction and wherein said hand held optical reader is disposed in a common local facility with a spaced apart host processor having an associated display; and

(b) wirelessly sending from said spaced apart host processor to said hand held optical reader at least one of said light source flashing component control instruction, said acoustic output device component control instruction, and said display output component control instruction, whereby a user-perceivable result is produced by said hand held optical reader substantially on receipt of said at least one component control instruction so that attention of an operator of said hand held optical reader is attracted.

7. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said light source flashing component control instruction from said spaced apart host processor to said hand held optical reader.

8. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said light source flashing component control instruction from said spaced apart host processor to said hand held optical reader so that substantially on receipt of said light source flashing component control instruction, said hand held optical reader directs LED light toward a target of said hand held optical reader.

9. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said acoustic output component control instruction from said spaced apart host processor to said hand held optical reader.

10. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said display output component control instruction from said spaced apart host processor to said hand held optical reader.

11. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said light source flashing component control instruction from said spaced apart host processor to said hand held optical reader, and wirelessly sending said acoustic output component control instruction from said spaced apart host processor to said hand held optical reader.

12. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said light source flashing component control instruction from said spaced apart host processor to said hand held optical reader, and wirelessly sending said display output component control instruction from said spaced apart host processor to said hand held optical reader.

13. The method of claim **6**, wherein said wirelessly sending step includes the step of wirelessly sending said acoustic output component control instruction from said spaced apart host processor to said hand held optical reader, and wirelessly sending said display output component control instruction from said spaced apart host processor to said hand held optical reader.

14. The method of claim **6**, wherein said method further includes the step of initiating said component control instruction by presenting at a location spaced apart from said hand held optical reader a user-input command to control said hand held optical reader.

15. The method of claim **6**, wherein said method further includes the step of inputting a command using said host processor to initiate said at least one component control instruction.

16. A system comprising:

(a) an optical reader including an imaging assembly, a display, a keyboard, a wireless communication link, a light source, an acoustic output device and a controller configured to capture image data and decode decodable bar code symbols therein, said optical reader further including a hand held housing encapsulating said imaging assembly and said controller, said hand held housing further supporting said display and said keyboard; and

(b) a host processor spaced apart from said optical reader, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is configured so that in a first mode said host processor wirelessly sends to said optical reader a beeper control instruction, wherein said optical reader substantially on receipt of said beeper control instruction actuates said acoustic output device so that said acoustic output device emits a series of beeps;

(d) wherein said system is further configured so that in a second mode said host processor sends to said optical reader a display control instruction, wherein said optical reader substantially on receipt of said display control instruction causes indicia to be displayed on said display; and

(e) wherein said system is configured so that said host processor in a further mode sends to said optical reader a light source control instruction, said optical reader substantially on receipt of said light source instruction causes light from said light source to be directed toward a target of said optical reader without causing actuation of said imaging assembly.

17. The system of claim **16**, wherein said acoustic output device is a speaker.

18. The system of claim **16**, wherein said imaging assembly includes a two dimensional solid state image sensor.

19. The system of claim **16**, wherein said system is configured so that said beeper control instruction sent by said host processor in said first mode is initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader.

20. The system of claim **16**, wherein said system is configured so that said display control instruction sent by said host processor in said second mode is initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader.

21. The system of claim **16**, wherein said system is configured so that said beeper control instruction sent by said host processor in said first mode is initiated by a user of said host processor.

22. The system of claim **16**, wherein said system is configured so that said display control instruction sent by said host processor in said second mode is initiated by a user of said host processor.

23. A system comprising:

(a) a optical reader including an imaging assembly, a display, a keyboard, an acoustic output device and a controller configured to capture image data and decode decodable bar code symbols therein, said optical reader further including a hand held housing encapsulating said imaging assembly and said controller, said hand held housing further supporting said display and said keyboard; and

(b) a host processor having an associated display spaced apart from said optical reader and being disposed at a common local facility with said optical reader, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is configured so that in a first mode said host processor sends to said optical reader a beeper control instruction that is initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader, wherein said optical reader substantially on receipt of said beeper control instruction actuates said acoustic output device so that said acoustic output device emits a series of beeps without actuating said display;

(d) wherein said system is further configured so that in a second mode said host processor sends to said optical reader a display control instruction, wherein said optical reader substantially on receipt of said display control instruction causes indicia to be displayed on said display without actuating said acoustic output device.

24. The system of claim **23**, wherein said optical reader further includes a light source, and wherein said system is configured so that said host processor in a further mode sends to said optical reader a light source control instruction, said optical reader substantially on receipt of said light source control instruction causes said light source to flash on and off.

25. The system of claim **23**, wherein said system is configured so that said display control instruction sent by said host processor in said second mode is initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader.

26. The system of claim **23**, wherein said imaging assembly includes a two dimensional solid state image sensor.

27. The system of claim **23**, wherein said system is configured so that said display control instruction sent by said host processor in said second mode is initiated by a user of said host processor.

28. A system comprising:

(a) an optical reader including an imaging assembly, a display, a keyboard, an acoustic output device and a controller configured to capture image data and decode decodable indicia therein, said optical reader further including a hand held housing encapsulating said imaging assembly and said controller, said hand held housing further supporting said display and said keyboard; and

(b) a host processor having an associated display spaced apart from said optical reader, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is configured so that host processor can send to said optical reader a beeper control instruction, wherein said optical reader substantially on receipt of said beeper control instruction actuates said acoustic output device so that said acoustic output device emits a series of beeps without actuating said display;

(d) wherein said system is further configured so that said host processor can send said optical reader a display control instruction, wherein said optical reader substantially on receipt of said display control instruction causes a predetermined indicia to be displayed on said display without actuating said acoustic output device.

29. the system of claim **28**, wherein said optical reader further includes a light source, wherein said system is configured so that said host processor can send to said optical reader a light source control instruction, and wherein said optical reader substantially on receipt of said light source instruction causes said light source to flash on and off.

30. The system of claim **28**, wherein said acoustic output device is a speaker.

31. The system of claim **28**, wherein said imaging assembly includes a two dimensional solid state image sensor.

32. The system of claim **28**, wherein said display is provided by a liquid crystal display.

33. The system of claim **28**, wherein said host processor is disposed in a common local facility with said optical reader, and wherein said host processor includes an associated communication interface for providing communication between said host processor and a processor not disposed in a common local facility with said host processor.

34. A system comprising:

(a) an optical reader including an imaging assembly, a display, a keyboard, a wireless communication link, a light source, an acoustic output device and a controller configured to capture image data and decode decodable indicia therein, said optical reader further including a hand held housing encapsulating said imaging assembly and said controller, said hand held housing further supporting said display and said keyboard; and

(b) a host processor spaced apart from said optical reader, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable

between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is configured so that said host processor can wirelessly send to said optical reader a beeper control instruction, wherein said optical reader substantially on receipt of said beeper control instruction actuates said acoustic output device so that said acoustic device emits a series of beeps;

(d) wherein said system is further configured so that said host processor can send to said optical reader a display control instruction, wherein said optical reader substantially on receipt of said display control instruction causes indicia to be displayed on said display; and

(e) wherein said system is further configured so that said host processor can send to said optical reader a light source control instruction, said optical reader substantially on receipt of said light source control instruction causes light from said light source to be directed toward a target of said optical reader without causing actuation of said imaging assembly.

35. The system of claim **34**, wherein said acoustic output device is a speaker.

36. The system of claim **34**, wherein said imaging assembly includes a two dimensional solid state image sensor.

37. The system of claim **34**, wherein said system is configured so that said beeper control instruction that can be sent by said host processor and can be initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader.

38. The system of claim **34**, wherein said system is configured so that said display control instruction that can be sent by said host processor can be initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader.

39. The system of claim **34**, wherein said system is configured so that said beeper control instruction is transmitted from said host processor in response to a user input command input by a user of said host processor.

40. The system of claim **34**, wherein said system is configured so that said display control instruction is transmitted from said host processor in response to a user input command input by a user of said host processor.

41. The system of claim **34**, wherein said system is configured so that said light source control instruction is transmitted from said host processor in response to a user input command input by a user of said host processor.

42. The system of claim **38**, wherein said host processor is disposed in a common local facility with said optical reader, and wherein said host processor includes an associated communication interface for providing communication between said host processor and a processor not disposed in a common local facility with said host processor.

43. A system comprising:

(a) a optical reader including an imaging assembly, a display, a keyboard, an acoustic output device and a controller configured to capture image data and decode decodable indicia therein, said optical reader further including a hand held housing encapsulating said imaging assembly and said controller, said hand held housing further supporting said display and said keyboard; and

(b) a host processor having an associated display spaced apart from said optical reader and being disposed at a common local facility with said optical reader, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is configured so that said host processor can send to said optical reader a beeper control instruction that is initiated by a user of said host processor, wherein said optical reader substantially on receipt of said beeper control instruction actuates said acoustic output device so that said acoustic output device emits a series of beeps without actuating said display;

(d) wherein said system is further configured so that said host processor can send to said optical reader a display control instruction, wherein said optical reader substantially on receipt of said display control instruction causes indicia to be displayed on said display without actuating said acoustic output device.

44. The system of claim **43**, wherein said optical reader further includes a light source, and wherein said system is further configured so that said host processor can send to said optical reader a light source control instruction, and wherein said optical reader substantially on receipt of said light source control instruction can cause said light source to flash on and off.

45. The system of claim **43**, wherein said system is configured so that said display control instruction sent by said host processor can be initiated by a user by presenting at a location spaced apart from said optical reader a command to control said optical reader.

46. The system of claim **43**, wherein said imaging assembly includes a two dimensional solid state image sensor.

47. The system of claim **43**, wherein said host processor includes an associated communication interface for providing communication between said host processor and a processor not disposed in a common local facility with said host processor.

48. A method for attracting attention of an operator of a hand held optical reader, said method comprising the steps of:

(a) providing a hand held optical reader having an artificial light source directing light toward a target, an acoustic output device, said hand held optical reader having a display and further being configured to decode decodable bar code symbols represented in captured image data,

(b) providing a spaced apart host processor spaced apart from said hand held optical reader, said spaced apart host processor being disposed in a common local facility with said hand held optical reader having a user interface including a display;

(c) configuring said hand held optical reader to receive at least one component control instruction from a spaced apart host processor, said component control instruction being selected from the group consisting of a light source component control instruction which when executed by said hand held optical reader results in light from said artificial light source being directed toward a target of said optical reader without a frame of image data being captured, and an acoustic output device component control instruction which when executed by said hand held optical reader causes said acoustic output device to be actuated without a frame of image data being captured, wherein said configuring step includes the step of configuring said hand held optical reader to execute said at least one component control instruction to produce a user-perceivable result substantially on receipt of said component control instruction; and

(d) wirelessly sending from said spaced apart host processor to said hand held optical reader at least one of said light source component control instruction, and said acoustic output device component control instruction, whereby a user-perceivable result is produced by said

hand held optical reader substantially on receipt of said at least one component control instruction so that attention of an operator of said hand held optical reader is attracted.

49. The method of claim **48**, wherein said user-perceivable result is said light source being flashed.

50. The method of claim **48**, wherein said user-perceivable result is a series of beeps being emitted by said acoustic output device.

51. The method of claim **48**, wherein said sending step includes the step of sending responsively to a command being input to said spaced apart host processor by a user of said host processor.

52. The method of claim **48**, wherein said providing step includes the step of providing said host processor so that said host processor includes an associated communication interface for providing communication between said host processor and a processor not disposed in a common local facility with said host processor.

53. A method for signaling an alarm condition to an operator of a hand held optical reader, said method comprising the steps of:

(a) providing a hand held optical reader having an artificial light source for use in directing light toward a target, an acoustic output device, said hand held optical reader having a display and further being configured to decode decodable bar code symbols represented in captured image data,

(b) providing a spaced apart host processor spaced apart from said hand held optical reader, said spaced apart host processor being disposed in a common local facility with said hand held optical reader, said spaced apart host processor having a user interface including a display;

(c) configuring said hand held optical reader to receive at least one component control instruction from a spaced apart host processor, wherein said configuring step includes the step of configuring said hand held optical reader to receive a light source component control instruction and an acoustic output device component control instruction, wherein said light source component control instruction when executed by said hand held optical reader results in light from said artificial light source being directed toward a target of said optical reader without image data being captured and wherein said acoustic output device component control instruction which when executed by said hand held optical reader causes said acoustic output device to be actuated without image data being captured, wherein said configuring step further includes the step of configuring said hand held optical reader to execute said at least one component control instruction to produce a user-perceivable result substantially on receipt of said component control instruction and wherein said hand held optical reader is further configured to receive a frame capture component control instruction and an image upload component control instruction, the frame capture component control instruction when executed by said hand held optical reader resulting in a frame of image data presently in a field of view of said hand held optical reader being captured, and the image upload component control instruction when executed by said hand held optical reader resulting in a last captured frame of image data being uploaded to said spaced apart host processor; and

(d) wirelessly sending from said spaced apart host processor to said hand held optical reader at least one of said light source component control instruction, and said acoustic output device component control instruction, whereby a user-perceivable result is produced by said hand held optical reader substantially on receipt of said at least one component control instruction so that an alarm condition is indicated to an operator of said hand held optical reader.

54. The method of claim **53**, wherein said user-perceivable result is said light source being flashed.

55. The method of claim **53**, wherein said user-perceivable result is a series of beeps being emitted by said acoustic output device.

56. The method of claim **53**, wherein said sending step includes the step of sending responsively to a command being input to said spaced apart host processor by a user of said host processor.

57. The method of claim **53**, wherein said providing step includes the step of providing said host processor so that said host processor includes an associated communication interface for providing communication between said host processor and a processor not disposed in a common local facility with said host processor.

58. A system for attracting attention of an operation of an optical reader, said system comprising:

(a) an optical reader including an imaging assembly, a display, a keyboard, a wireless communication link, an illumination assembly comprising at least one light source, said illumination assembly for directing light in a direction of a target object, said optical reader further having a controller configured to capture image data and decode decodable indicia therein, said optical reader further including a hand held housing encapsulating said imaging assembly, said controller and said illumination assembly, said hand held housing further supporting said display and said keyboard; and

(b) a host processor spaced apart from said optical reader and being disposed in a common local facility with said optical reader, wherein said host processor has an associated keyboard and an associated communication interface for providing communication with processor not disposed in said common local facility, wherein said hand held housing is adapted to be held in a human hand so that said optical reader is moveable between a variety of orientations and distances with respect to said host processor;

(c) wherein said system is further configured so that said host processor can send to said optical reader a light source control instruction,

(d) wherein said system is further configured so that said optical reader, substantially on receipt of said light source control instruction causes said illumination assembly to direct light toward a target of said optical reader without causing actuation of said imaging assembly.

59. The system of claim **58**, wherein said imaging assembly includes a two dimensional solid state image sensor.

60. The system of claim **58**, wherein said system is configured so that said light source control instruction is transmitted from said host processor in response to a user input command input by a user of said host processor.

61. The system of claim **58**, wherein said illumination assembly includes a plurality of light sources.

62. The system of claim **58**, wherein said illumination assembly includes a plurality of LEDs.

* * * * *

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(12) **United States Patent**
Parker et al.

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(54) **REPROGRAMMABLE OPTICAL READER**

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(51) **Int. Cl.**
G06K 7/10 (2006.01)

(52) **U.S. Cl.** **235/486**; 235/383; 235/472.01

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See application file for complete search history.

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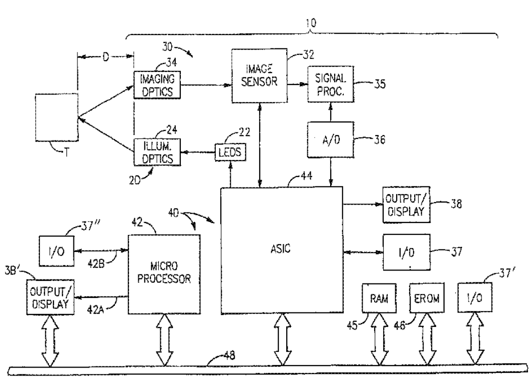
(57) **ABSTRACT**

A programmable optical reader in one embodiment can include a program loading component and a program execution component operative to execute an externally generated program, whereby executing the externally generated program includes replacing a portion of the optical reader program. A programmable optical reader in another embodiment can include a two-dimensional image sensor, an image frame memory storing two-dimensional electronic images, and can be configured to be reprogrammed by any one of receipt of reprogramming data from a local host processor or receipt of programming data from an external remote off-site processor.

64 Claims, 32 Drawing Sheets



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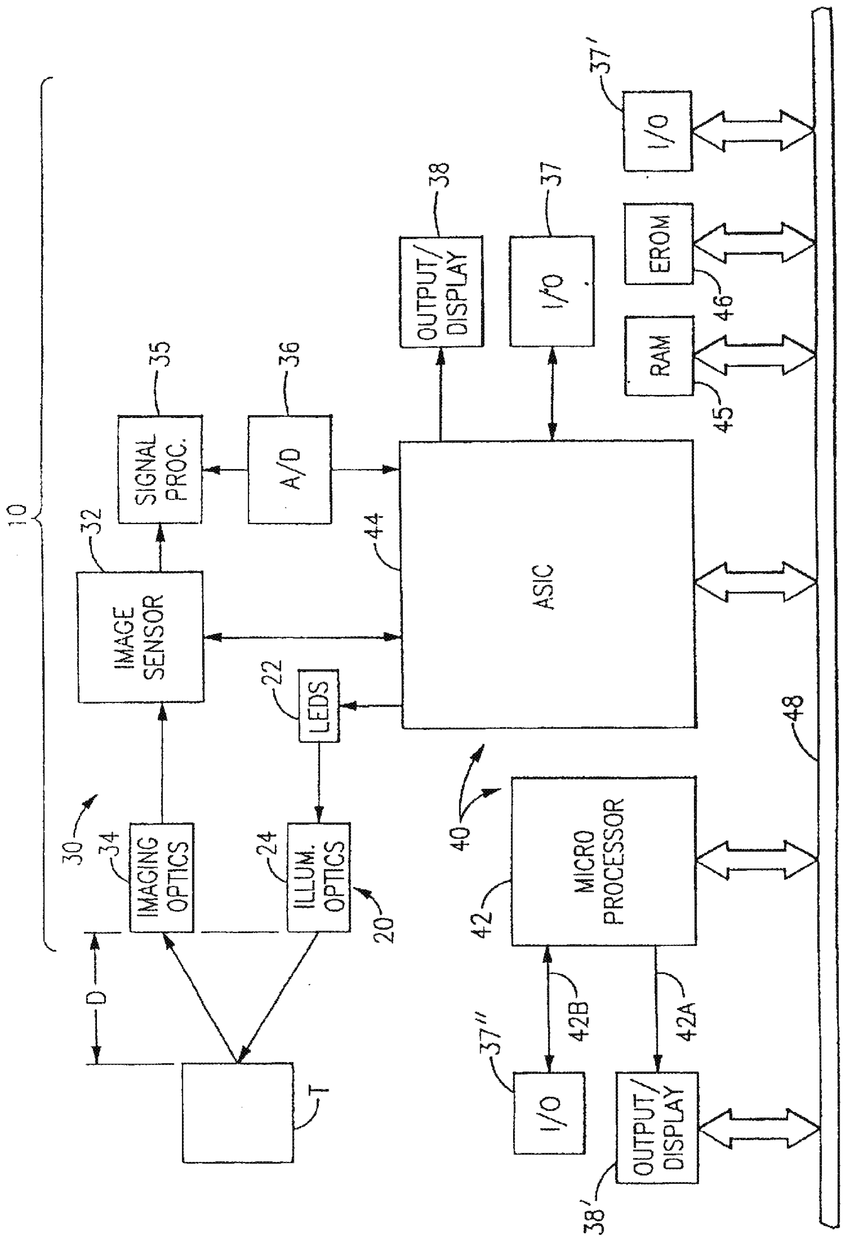
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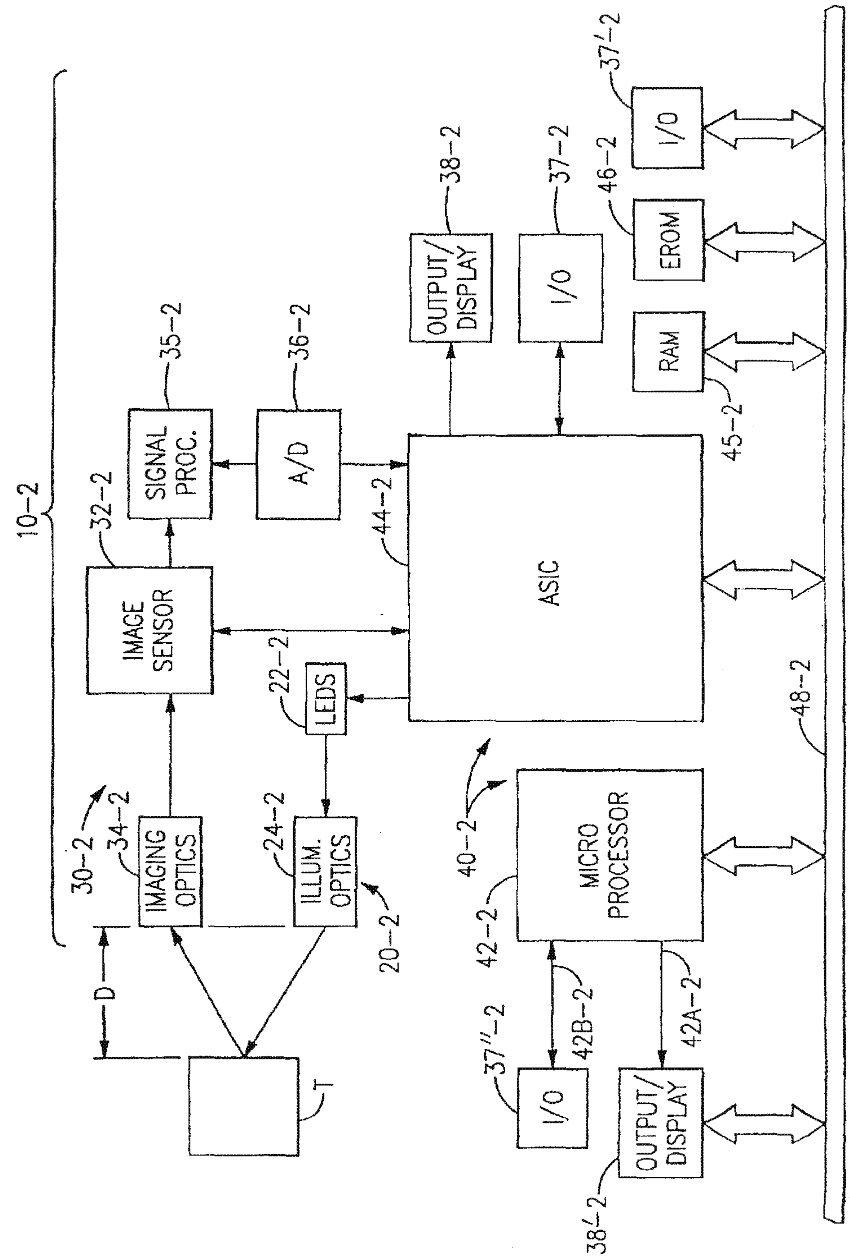
SIGNAL PROC.
A/D
ASIC
OUTPUT/ DISPLAY
I/O
RAM
EROM
LEDS
IMAGING OPTICS
ILLUM. OPTICS
MICRO PROCESSOR
D
T
30
34
32
35
36
38
37
37′
44
45
46
22
24
20
40
42
42A
42B
37″
38′
48

FIG.1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35-2
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ASIC
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LEDS
22-2
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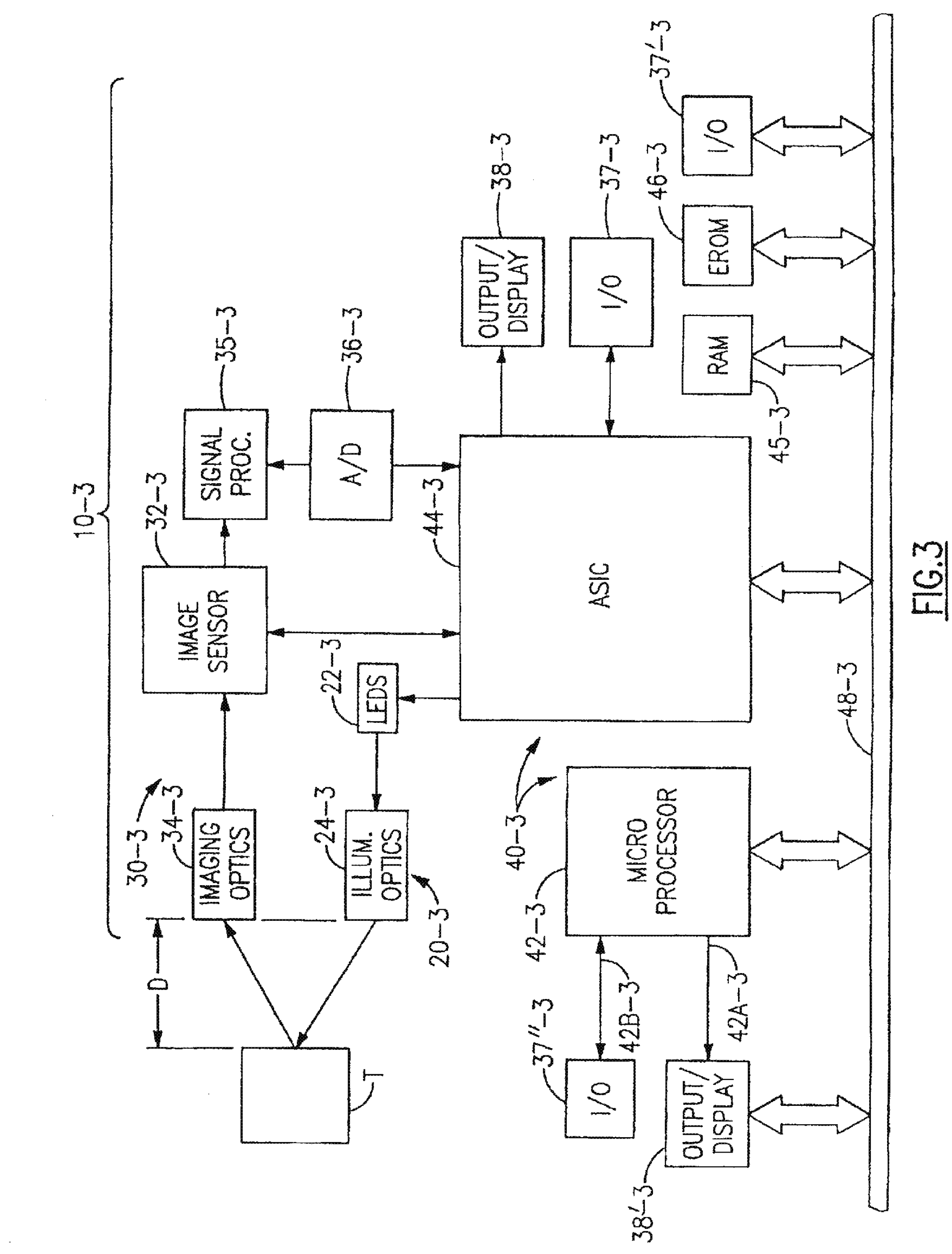
34-2
30-2
ILLUM. OPTICS
24-2
20-2
D
T
OUTPUT/ DISPLAY
38-2
I/O
37-2
RAM
45-2
EROM
46-2
I/O
37'-2
MICRO PROCESSOR
40-2
42-2
42B-2
42A-2
I/O
37''-2
OUTPUT/ DISPLAY
38'-2
48-2

FIG.2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20–3
IMAGE SENSOR
32–3
SIGNAL PROC.
35–3
A/D
36–3
LEDS
22–3
ASIC
44–3
OUTPUT/ DISPLAY
38–3
I/O
37–3
RAM
45–3
EROM
46–3
I/O
37'–3
MICRO PROCESSOR
40–3
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42A–3
I/O
37''–3
OUTPUT/ DISPLAY
38'–3
48–3
D
T

FIG.3

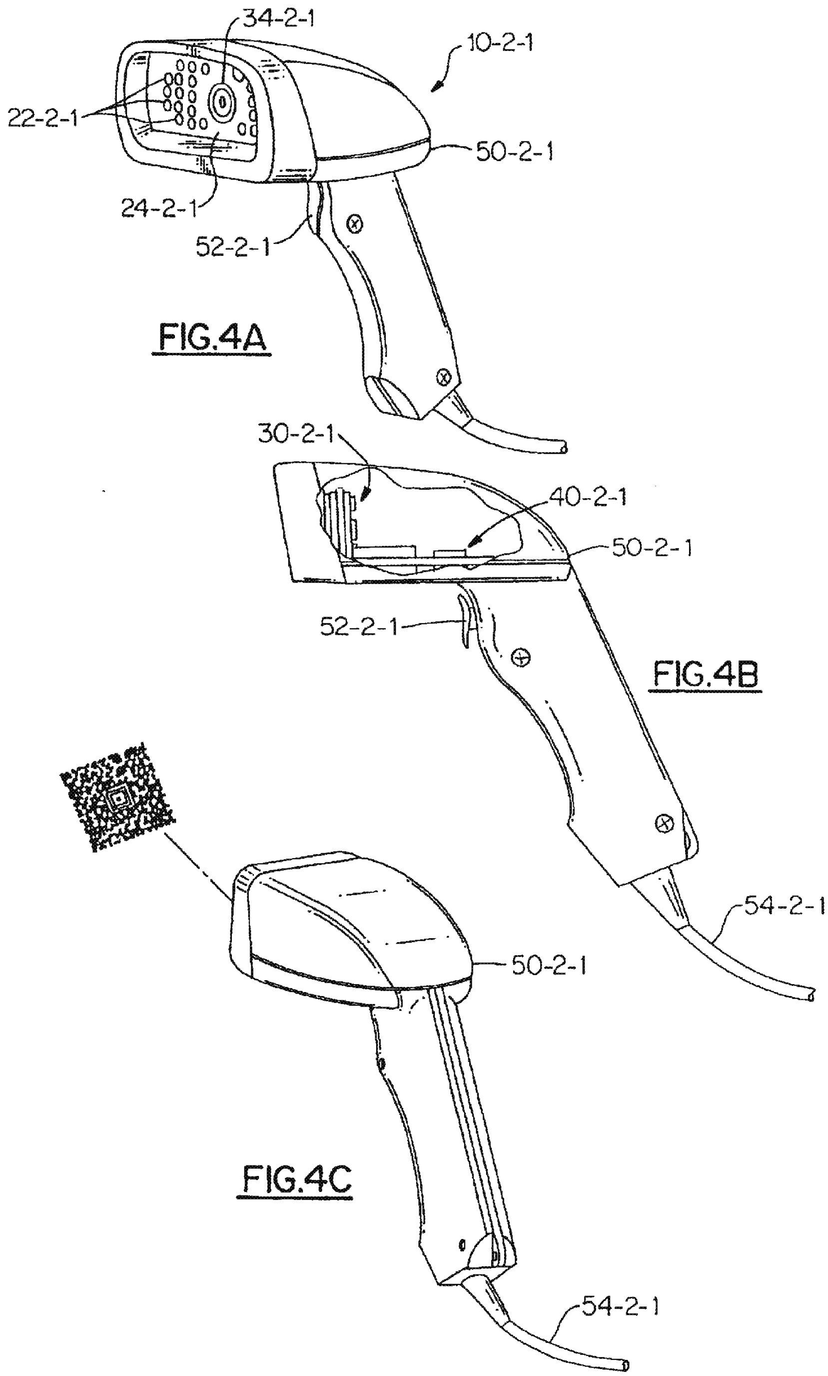


FIG.4A

FIG.4B

FIG.4C

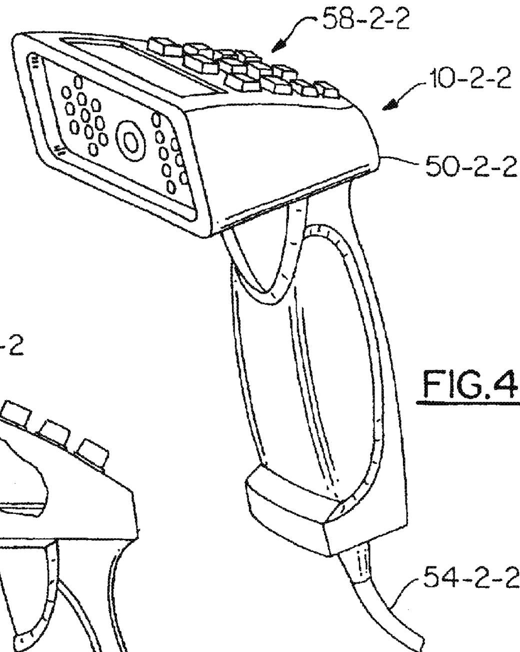


FIG.4D

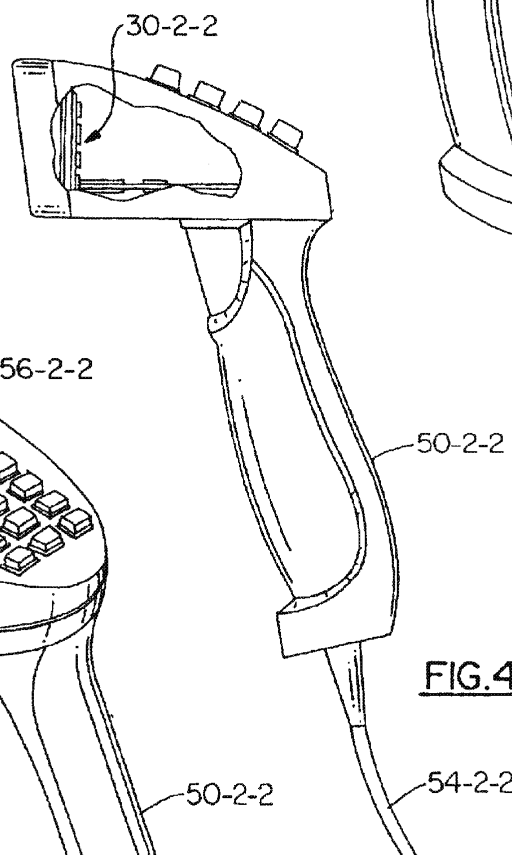


FIG.4E

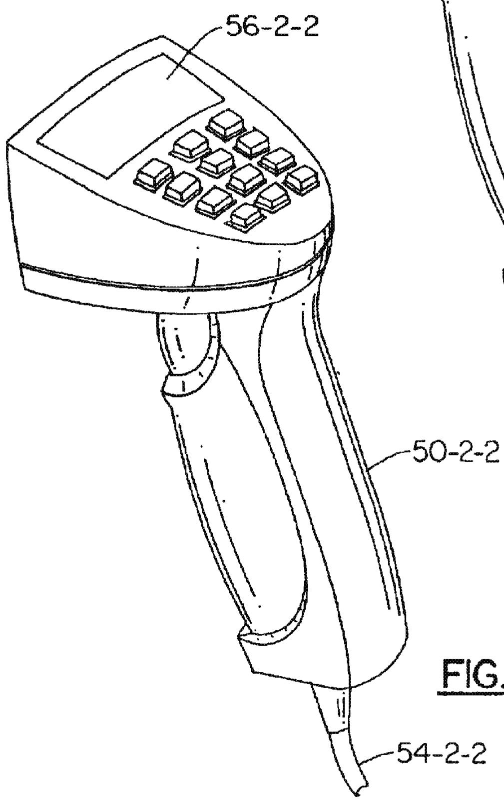


FIG.4F

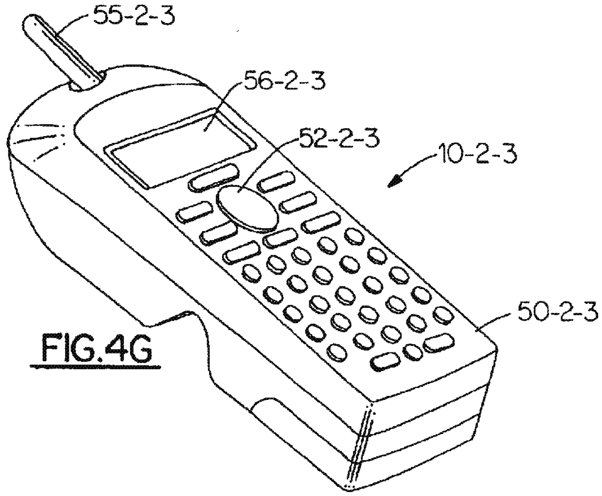


FIG.4G

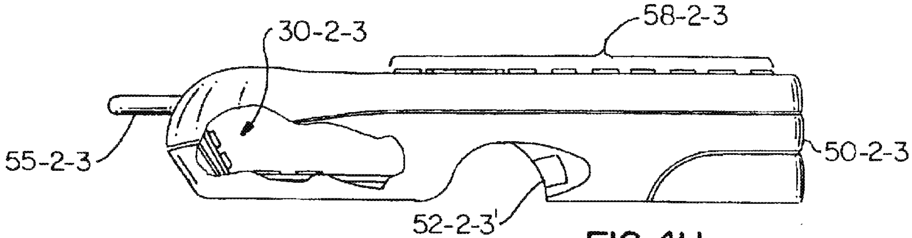


FIG.4H

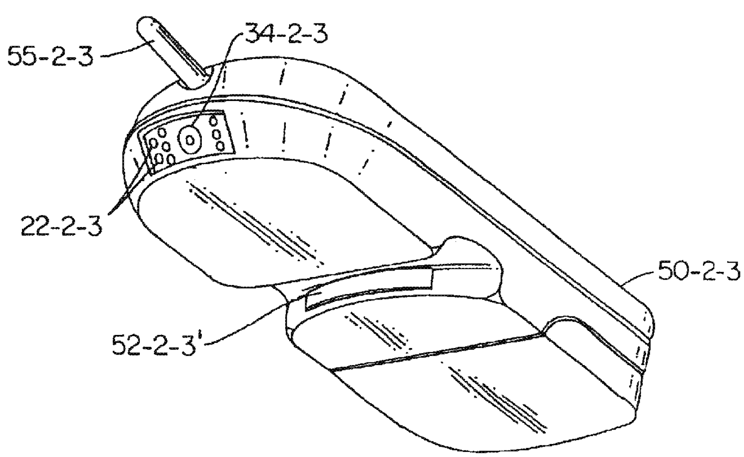


FIG.4I

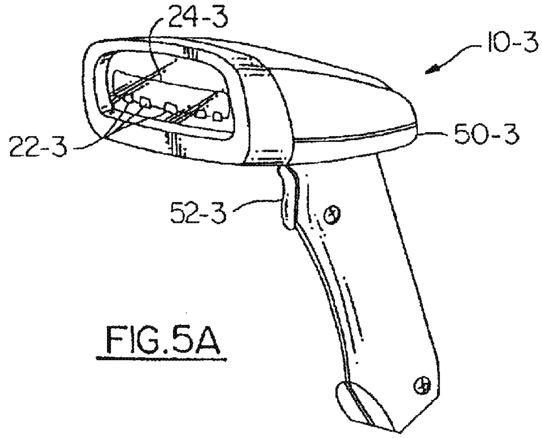


FIG.5A

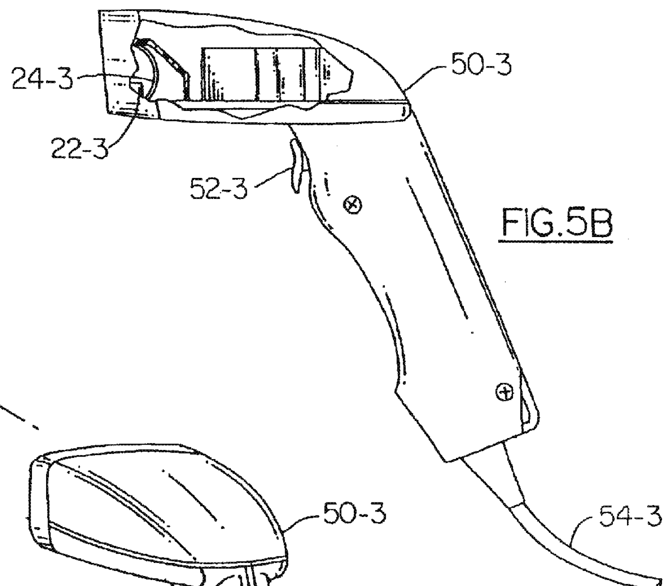


FIG.5B

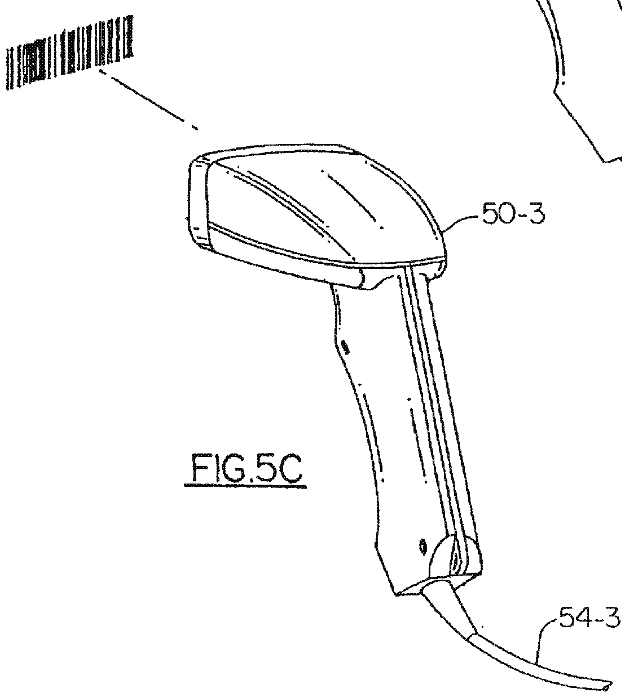
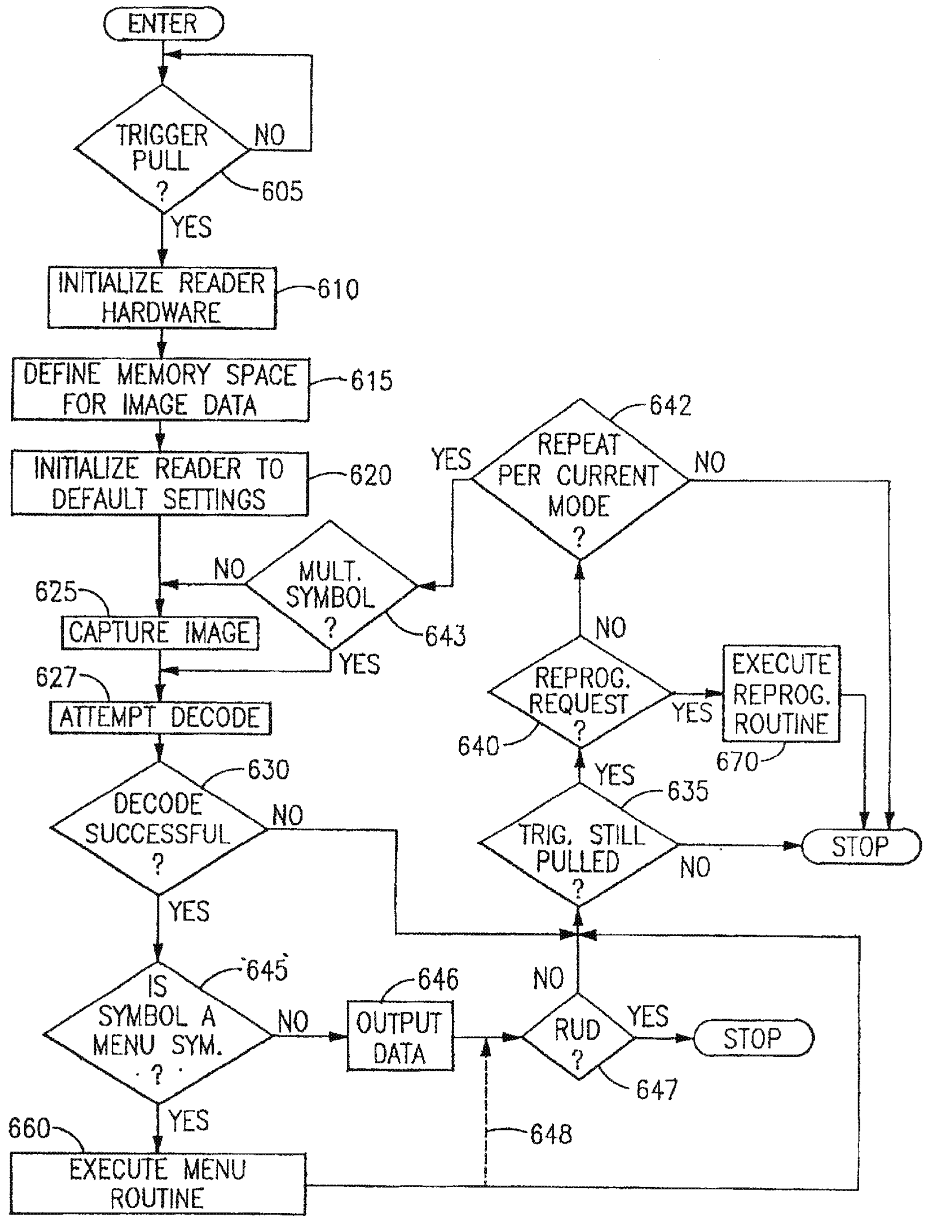


FIG.5C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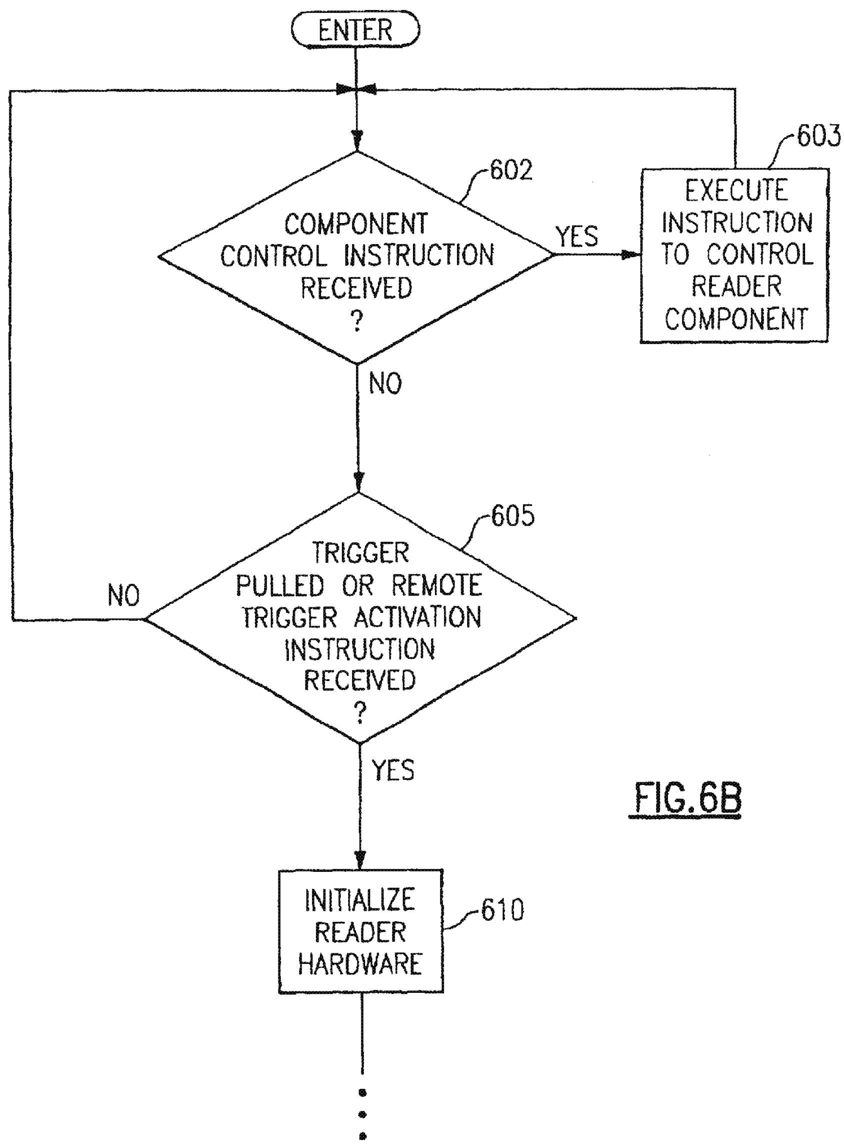
NO
605
YES
INITIALIZE READER HARDWARE
610
DEFINE MEMORY SPACE FOR IMAGE DATA
615
INITIALIZE READER TO DEFAULT SETTINGS
620
625
CAPTURE IMAGE
NO
MULT. SYMBOL ?
643
YES
627
ATTEMPT DECODE
DECODE SUCCESSFUL ?
630
NO
YES
IS SYMBOL A MENU SYM. ?
645
NO
YES
660
EXECUTE MENU ROUTINE
646
OUTPUT DATA
648
NO
RUD ?
YES
647
STOP
REPEAT PER CURRENT MODE ?
642
YES
NO
REPROG. REQUEST ?
640
YES
EXECUTE REPROG. ROUTINE
670
TRIG. STILL PULLED ?
635
NO
STOP

FIG. 6A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602
COMPONENT CONTROL INSTRUCTION RECEIVED ?
YES
603
EXECUTE INSTRUCTION TO CONTROL READER COMPONENT
NO
605
TRIGGER PULLED OR REMOTE TRIGGER ACTIVATION INSTRUCTION RECEIVED ?
NO
YES
INITIALIZE READER HARDWARE
610

FIG.6B

650-1	650-2	650-3	650-4	650-5	650-6	650-7
PRODUCT 1D CODE	OP CODE	OFFSET	DATA 0	DATA 1	DATA 2	DATA 3

650

FIG.7A

OPTIONS (OFFSET) TABLE

A. COMMUNICATIONS OPTIONS
  1. RS-232
  2. BAUD RATE
  3. RF LINK
  4. ETHERNET
B. CODE OPTIONS
  1. DISABLE 1D
  2. DISABLE 2D
  3. DISABLE INDIV.
  4. MIN-MAX LENGTH
  5. MULTIPLE SYMBOLS ENABLED
C. SCANNING-DECODING OPTIONS
  1. ONE SHOT
  2. REPEAT UNTIL DONE
  3. REPEAT UNTIL STOPPED
  4. SCAN ON DEMAND
  5. SKIP SCAN
  6. DECODE ON DEMAND
D. OPERATING OPTIONS
  1. BEEPER VOLUME
  2. AIMING LED ON/OFF
  3. AURAL FEEDBACK
E. TRANSMIT OPTIONS
  1. SEND CHECK CHAR'S
  2. SEND CHECKSUM
  3. DATA EDIT OPTIONS

FIG.7B

OP CODE TABLE

A. OP CODE "0"-VECTOR PROC.
  1. OUTPUT VERSION OF SOFTWARE
  2. OUTPUT CONTENTS OF PARAMETER TABLE
  3. DISPLAY ENABLED CODES
  4. PRINT PARAMETER TABLE AS BAR CODE SYMBOL
B. OP CODE "1" - CLEAR
C. OP CODE "2" - SET
D. OP CODE "3" - TOGGLE
E. OP CODE "4" - ADD
F. OP CODE "5" - DEFAULT
G. OP CODE "6" - LOAD
H. OP CODE "7" - RESERVED

FIG.7C

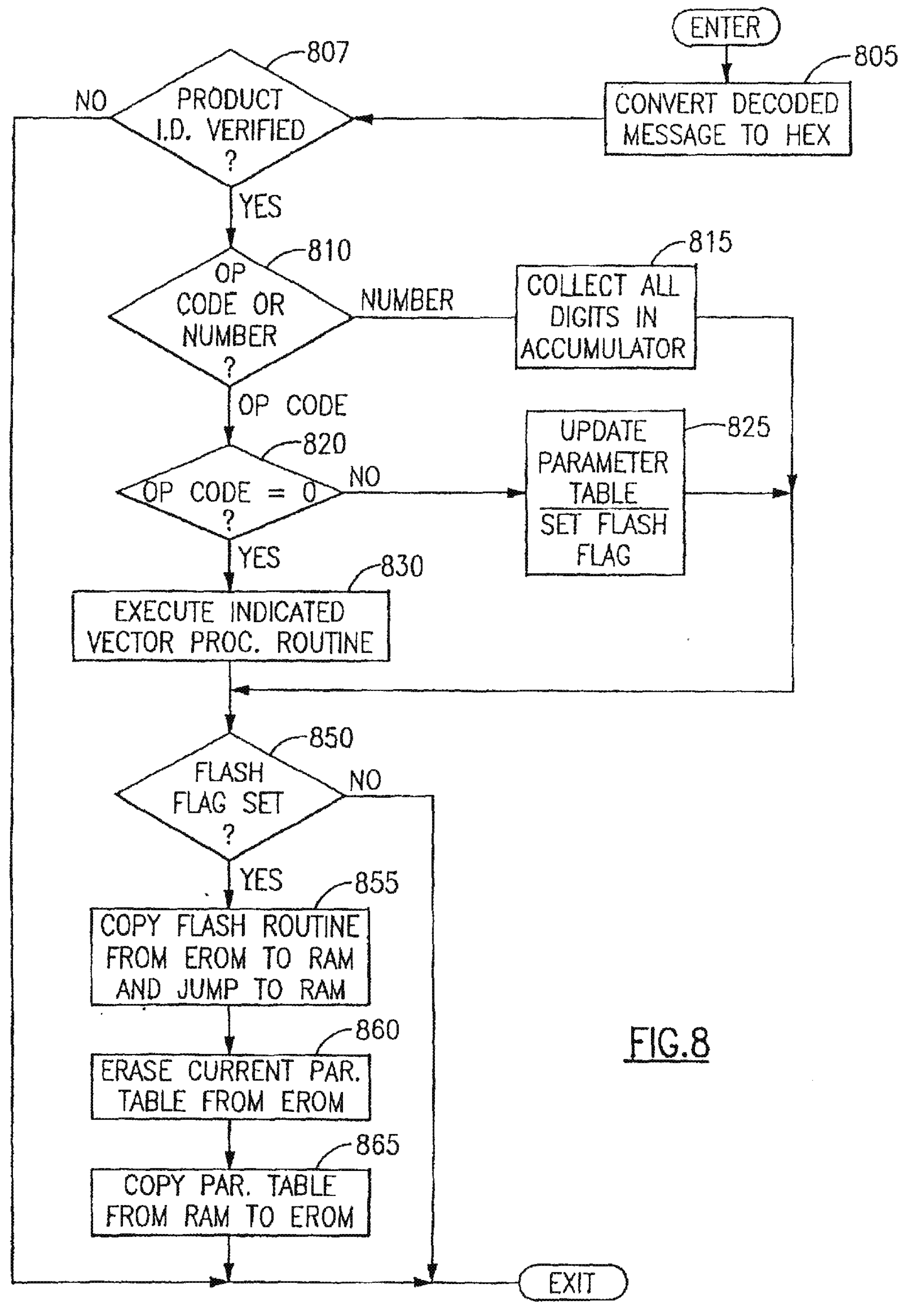

ENTER
805
CONVERT DECODED MESSAGE TO HEX
807
PRODUCT I.D. VERIFIED ?
NO
YES
810
OP CODE OR NUMBER ?
NUMBER
815
COLLECT ALL DIGITS IN ACCUMULATOR
OP CODE
820
OP CODE = 0 ?
NO
825
UPDATE PARAMETER TABLE
SET FLASH FLAG
YES
830
EXECUTE INDICATED VECTOR PROC. ROUTINE
850
FLASH FLAG SET ?
NO
YES
855
COPY FLASH ROUTINE FROM EROM TO RAM AND JUMP TO RAM
860
ERASE CURRENT PAR. TABLE FROM EROM
865
COPY PAR. TABLE FROM RAM TO EROM
EXIT

FIG.8

FIG.8A

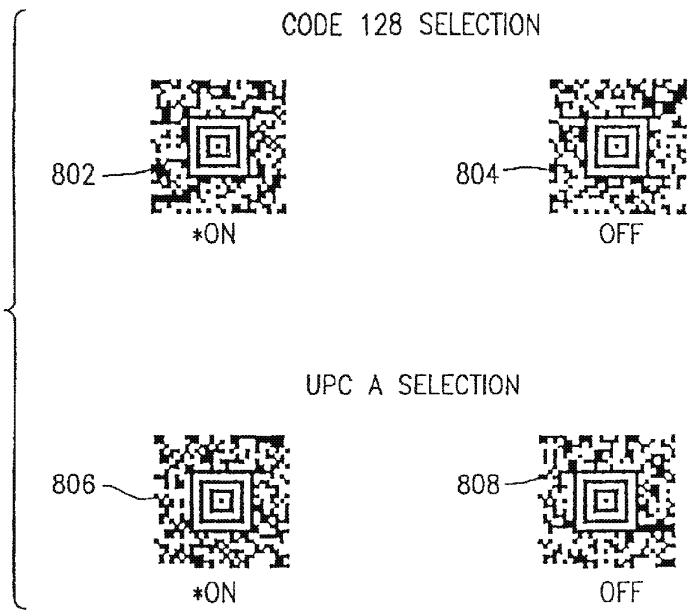

CODE 128 SELECTION
802
*ON
804
OFF
UPC A SELECTION
806
*ON
808
OFF

FIG.8B

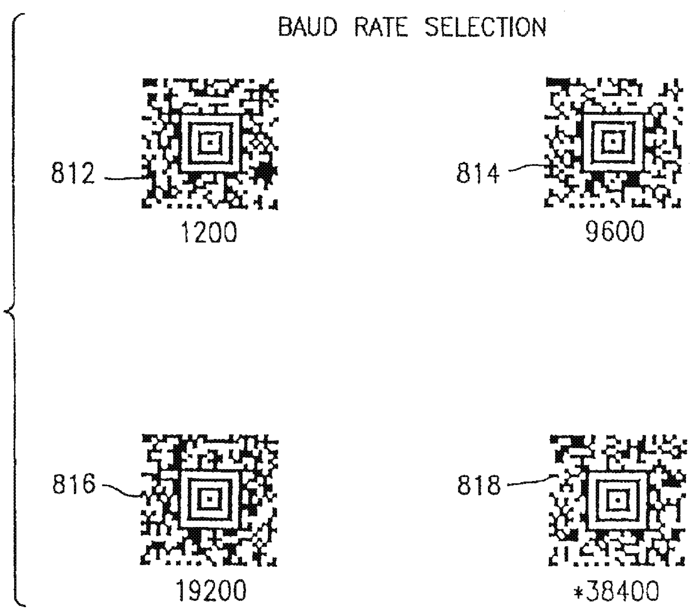

BAUD RATE SELECTION
812
1200
814
9600
816
19200
818
*38400

FIG.8C

DEFAULT ALL CODE 11/CODE 128 SETTINGS

822

CODE 11 SELECTION

824 — *ON

CODE 11

826 — OFF

828 — *2 CHECK DIGITS

CHECK DIGITS REQUIRED

832 — 1 CHECK DIGIT

834 — MINIMUM ‡

MESSAGE LENGTH

836 — MAXIMUM ‡

CODE 128 SELECTION

848 — *ON

CODE 128

852 — OFF

854 — MINIMUM ‡

MESSAGE LENGTH

856 — MAXIMUM ‡

‡ A TWO-DIGIT NUMBER IS REQUIRED AFTER SCANNING THIS PROGRAMMING BAR CODE. PLEASE SCAN YOUR SELECTION ON THE PROGRAMMING CHART (INSIDE BACK COVER).

FIG.8D

RS-232D PORT 2 (D OUTPUT)
DEFAULT ALL RS-232 PORT 2 SETTINGS

858

CTS CHECK SELECTION

862 ENABLE

864 *DISABLE

BAUD RATE SELECTION

866 300

868 600

872 1200

874 2400

876 4800

878 *9600

882 19200

884 38400

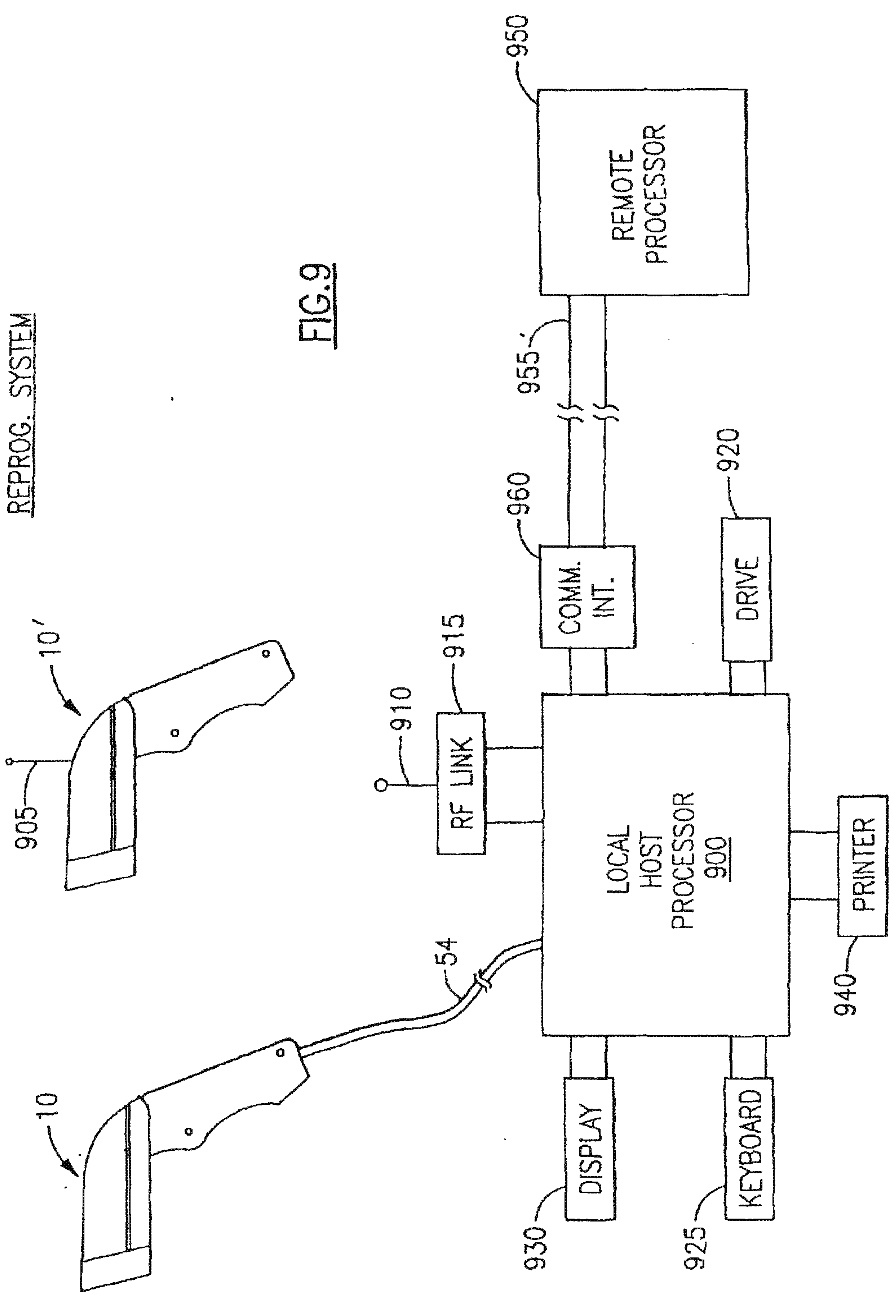

REPROG. SYSTEM
10′
905
10
54
910
915
RF LINK
960
COMM. INT.
955′
950
REMOTE PROCESSOR
920
DRIVE
LOCAL HOST PROCESSOR 900
PRINTER
940
DISPLAY
930
KEYBOARD
925

FIG.9

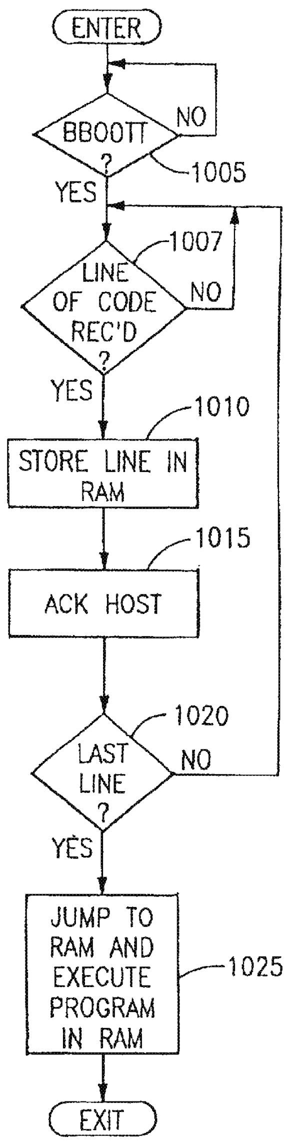


FIG. 10A

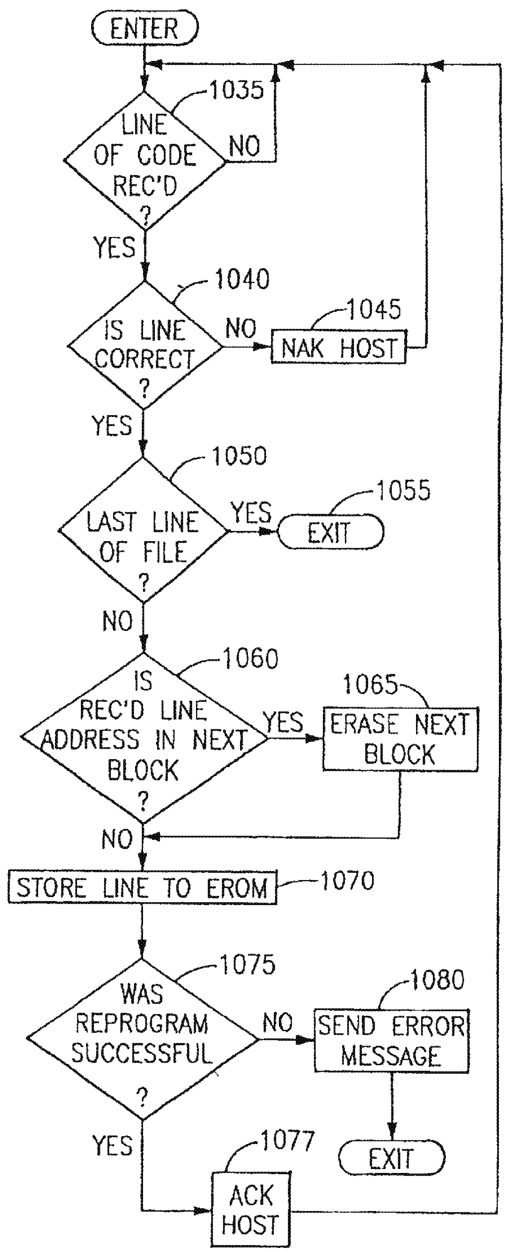
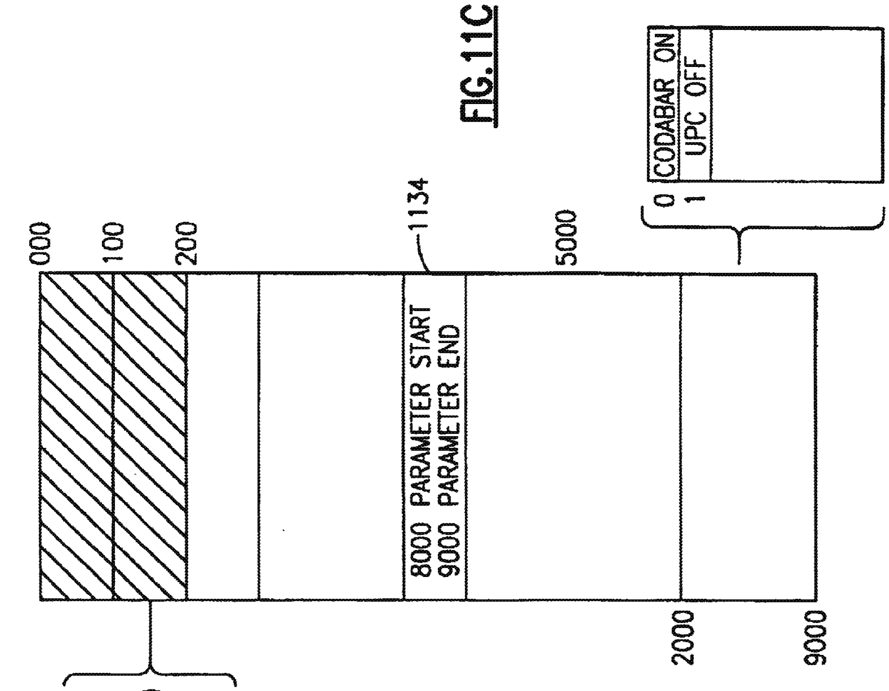


FIG. 10B

HONEYWELL-00161634

FIG.11C



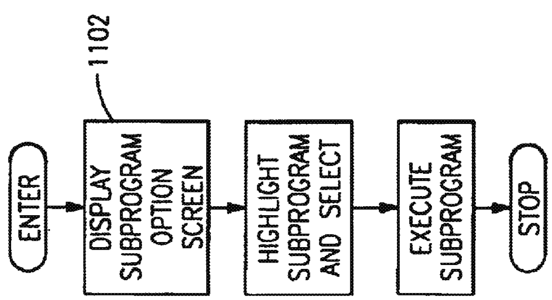


FIG.11A

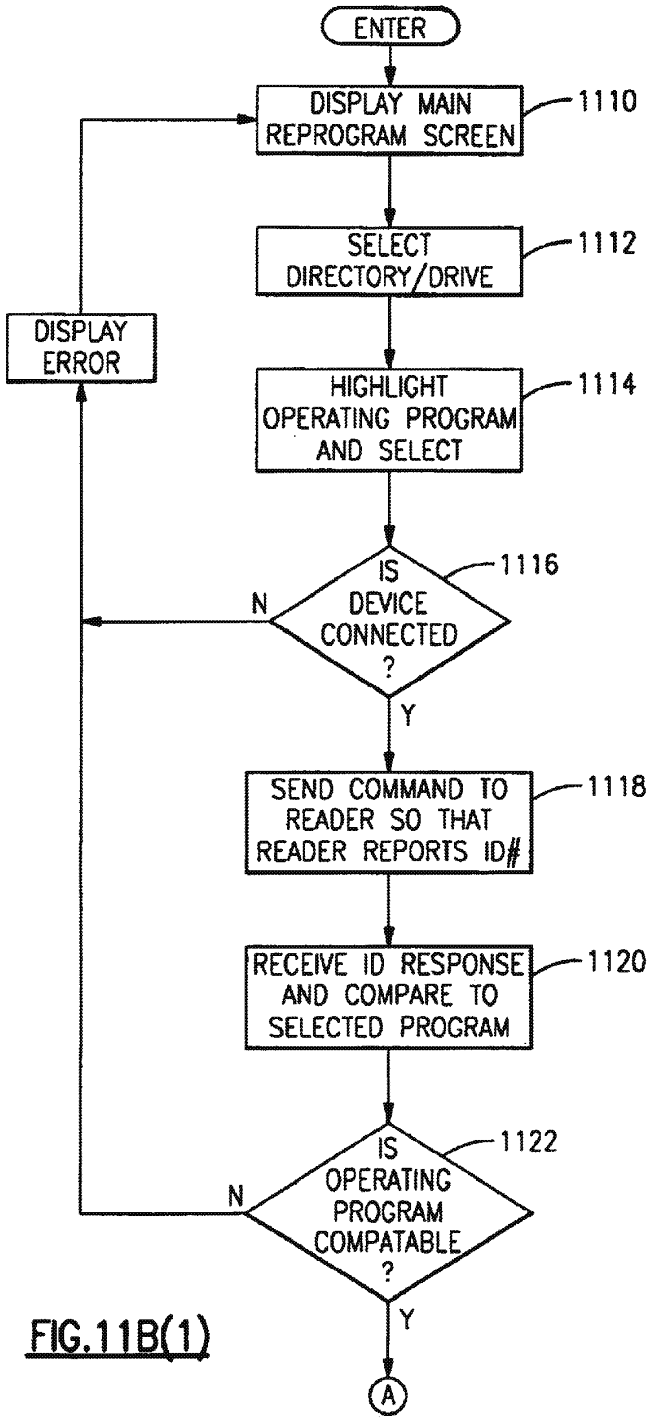


FIG.11B(1)

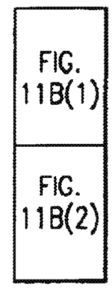


FIG.11B

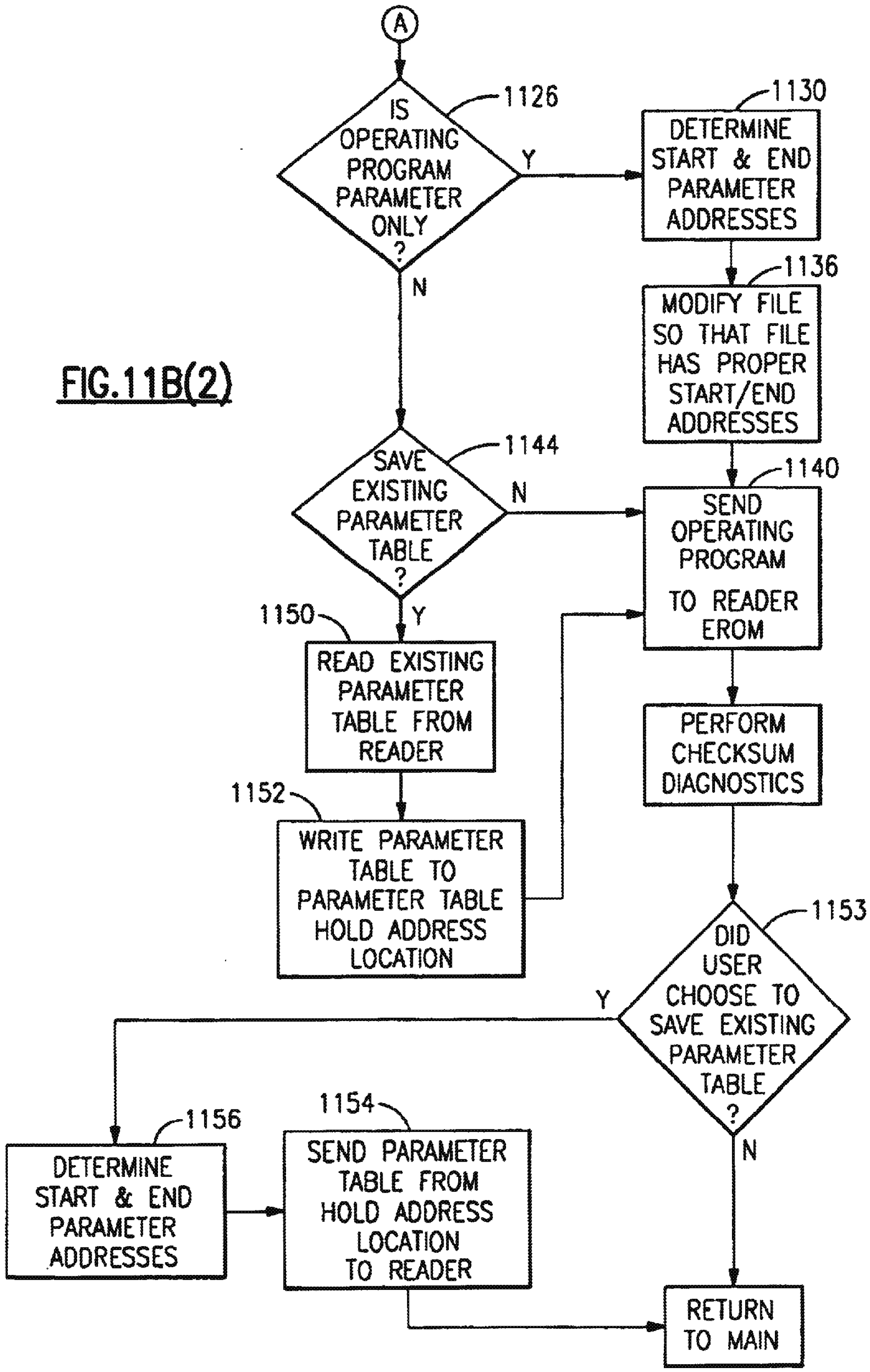

A
IS OPERATING PROGRAM PARAMETER ONLY ?
1126
Y
N
DETERMINE START & END PARAMETER ADDRESSES
1130
MODIFY FILE SO THAT FILE HAS PROPER START/END ADDRESSES
1136
SAVE EXISTING PARAMETER TABLE ?
1144
N
Y
SEND OPERATING PROGRAM TO READER EROM
1140
1150
READ EXISTING PARAMETER TABLE FROM READER
PERFORM CHECKSUM DIAGNOSTICS
1152
WRITE PARAMETER TABLE TO PARAMETER TABLE HOLD ADDRESS LOCATION
DID USER CHOOSE TO SAVE EXISTING PARAMETER TABLE ?
1153
Y
N
1156
DETERMINE START & END PARAMETER ADDRESSES
1154
SEND PARAMETER TABLE FROM HOLD ADDRESS LOCATION TO READER
RETURN TO MAIN

FIG.11B(2)

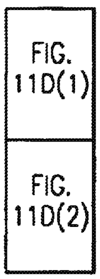


FIG.11D

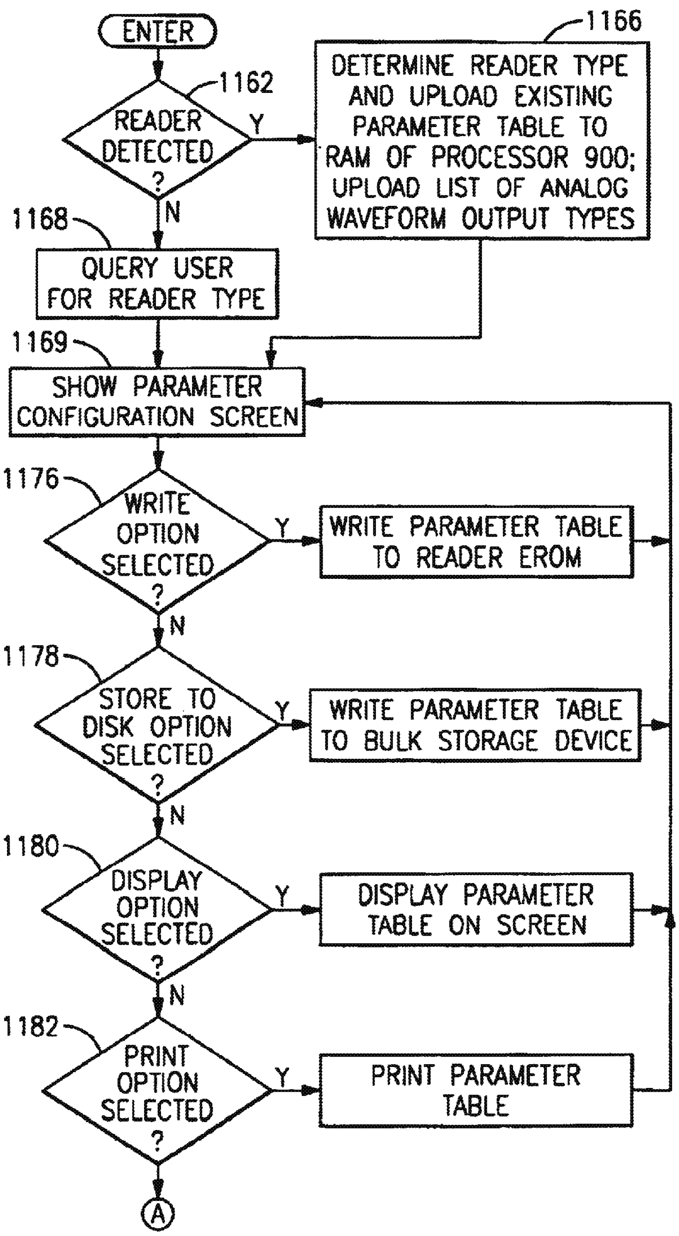
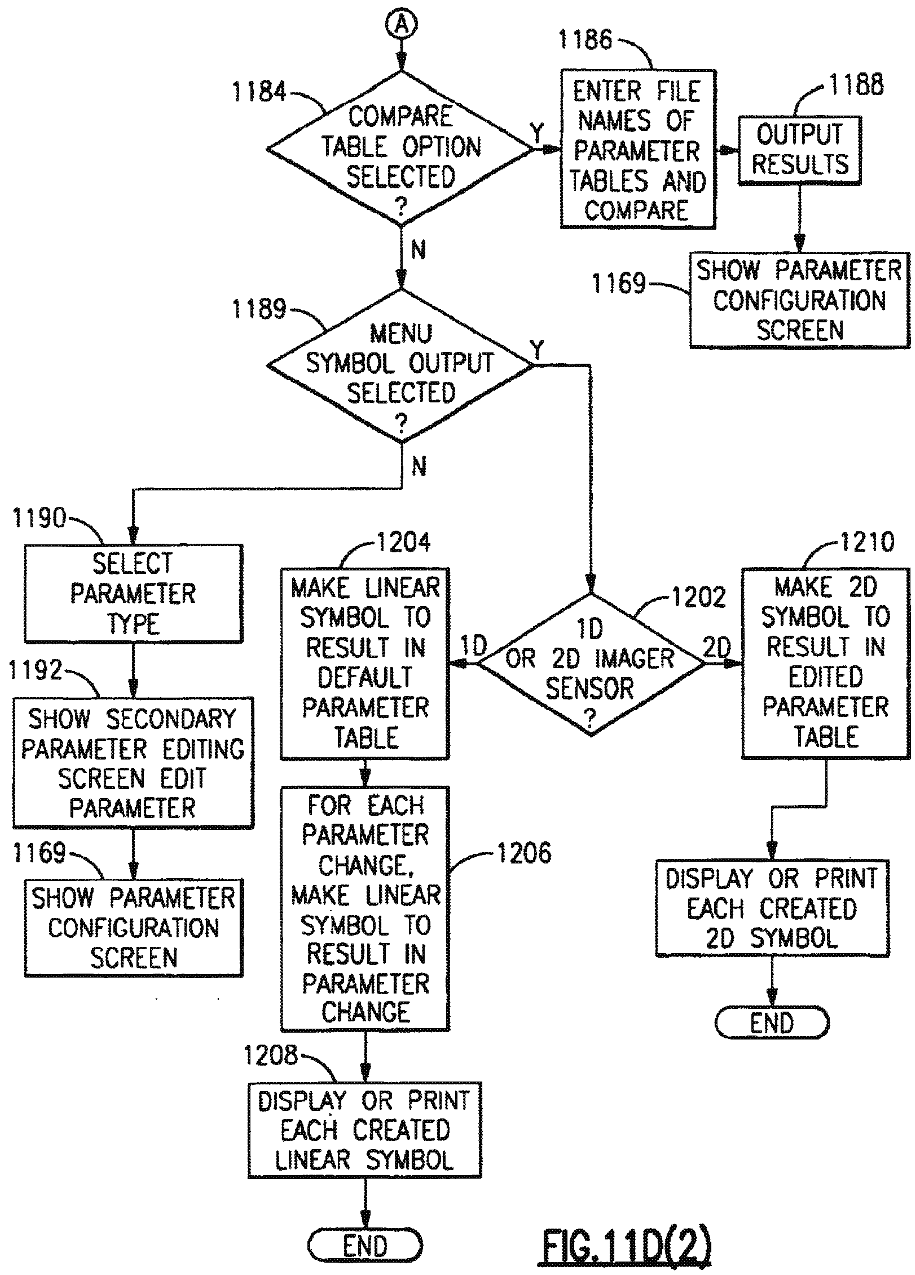
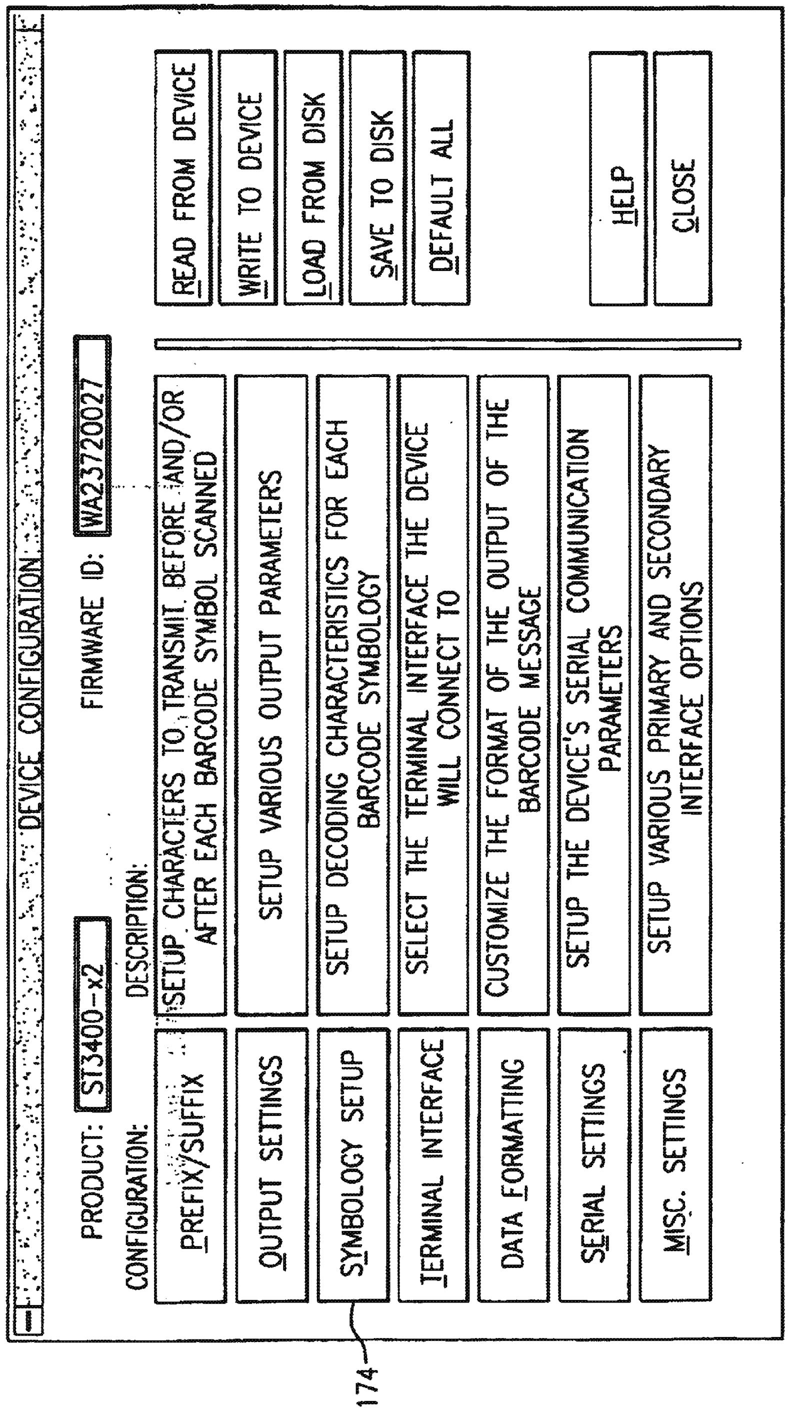


FIG.11D(1)



A
1184
COMPARE TABLE OPTION SELECTED ?
Y
1186
ENTER FILE NAMES OF PARAMETER TABLES AND COMPARE
1188
OUTPUT RESULTS
1169
SHOW PARAMETER CONFIGURATION SCREEN
N
1189
MENU SYMBOL OUTPUT SELECTED ?
Y
N
1190
SELECT PARAMETER TYPE
1192
SHOW SECONDARY PARAMETER EDITING SCREEN EDIT PARAMETER
1169
SHOW PARAMETER CONFIGURATION SCREEN
1204
MAKE LINEAR SYMBOL TO RESULT IN DEFAULT PARAMETER TABLE
1D
1202
1D OR 2D IMAGER SENSOR ?
2D
1210
MAKE 2D SYMBOL TO RESULT IN EDITED PARAMETER TABLE
1206
FOR EACH PARAMETER CHANGE, MAKE LINEAR SYMBOL TO RESULT IN PARAMETER CHANGE
DISPLAY OR PRINT EACH CREATED 2D SYMBOL
END
1208
DISPLAY OR PRINT EACH CREATED LINEAR SYMBOL
END

FIG.11D(2)



DEVICE CONFIGURATION
PRODUCT: ST3400-x2
FIRMWARE ID: WA23720027
CONFIGURATION:
DESCRIPTION:
PREFIX/SUFFIX
SETUP CHARACTERS TO TRANSMIT BEFORE AND/OR AFTER EACH BARCODE SYMBOL SCANNED
OUTPUT SETTINGS
SETUP VARIOUS OUTPUT PARAMETERS
SYMBOLOGY SETUP
SETUP DECODING CHARACTERISTICS FOR EACH BARCODE SYMBOLOGY
TERMINAL INTERFACE
SELECT THE TERMINAL INTERFACE THE DEVICE WILL CONNECT TO
DATA FORMATTING
CUSTOMIZE THE FORMAT OF THE OUTPUT OF THE BARCODE MESSAGE
SERIAL SETTINGS
SETUP THE DEVICE'S SERIAL COMMUNICATION PARAMETERS
MISC. SETTINGS
SETUP VARIOUS PRIMARY AND SECONDARY INTERFACE OPTIONS
READ FROM DEVICE
WRITE TO DEVICE
LOAD FROM DISK
SAVE TO DISK
DEFAULT ALL
HELP
CLOSE
1174

FIG.11E

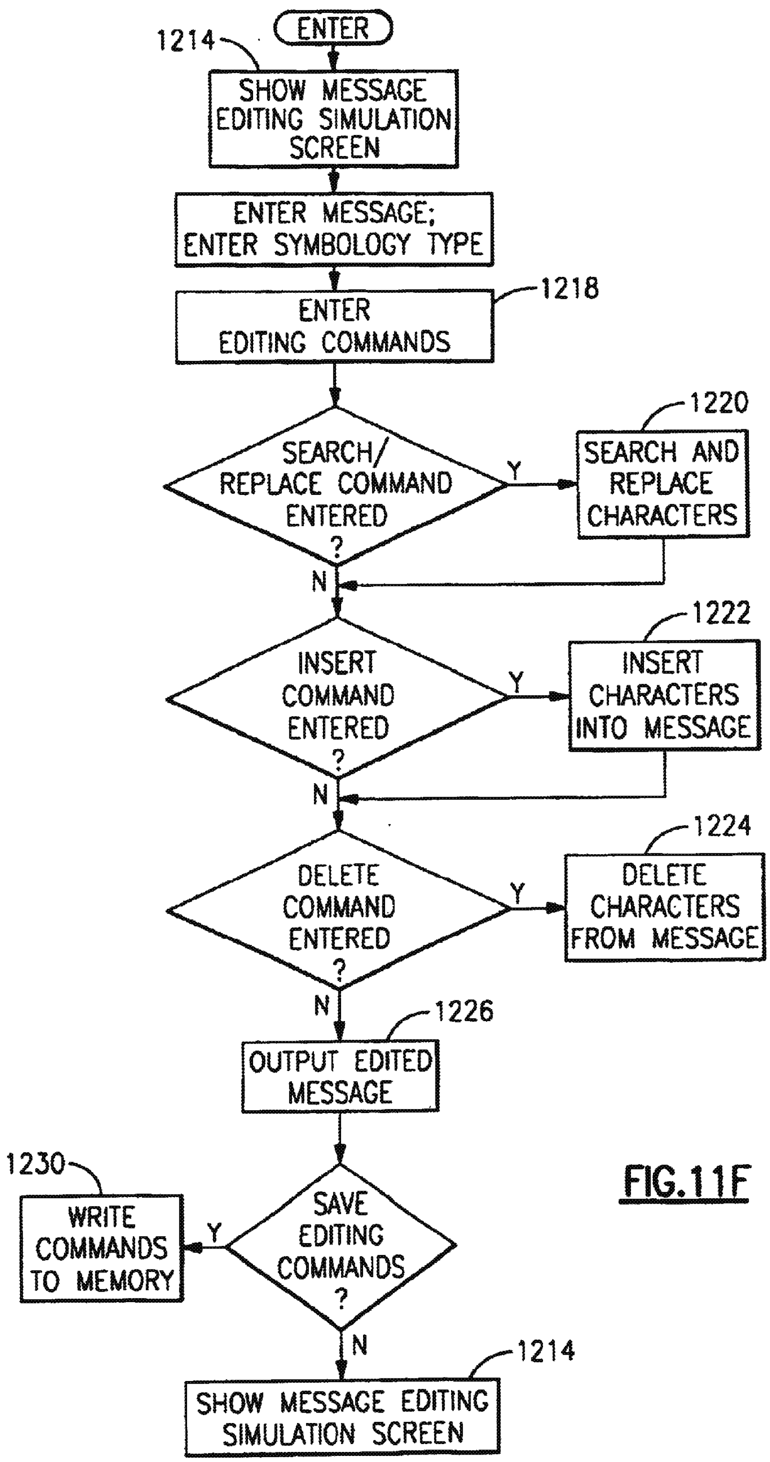

ENTER
1214
SHOW MESSAGE EDITING SIMULATION SCREEN
ENTER MESSAGE; ENTER SYMBOLOGY TYPE
1218
ENTER EDITING COMMANDS
SEARCH/ REPLACE COMMAND ENTERED ?
Y
N
1220
SEARCH AND REPLACE CHARACTERS
INSERT COMMAND ENTERED ?
Y
N
1222
INSERT CHARACTERS INTO MESSAGE
DELETE COMMAND ENTERED ?
Y
N
1224
DELETE CHARACTERS FROM MESSAGE
1226
OUTPUT EDITED MESSAGE
SAVE EDITING COMMANDS ?
Y
N
1230
WRITE COMMANDS TO MEMORY
1214
SHOW MESSAGE EDITING SIMULATION SCREEN

FIG.11F

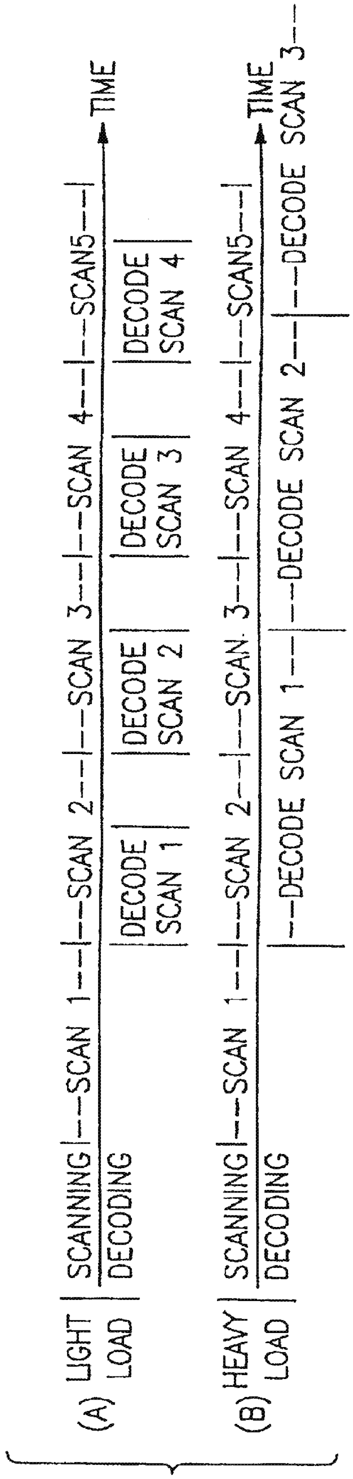


FIG.12
Prior Art

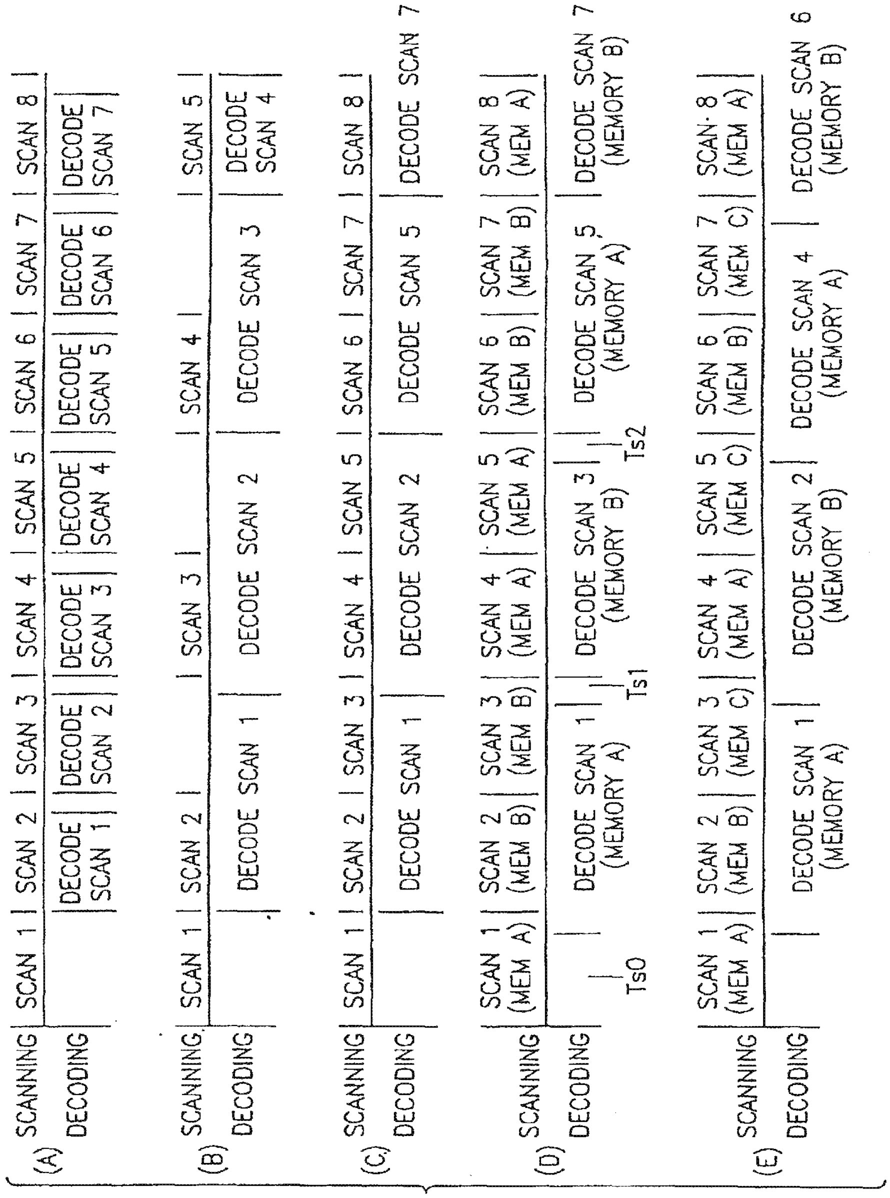
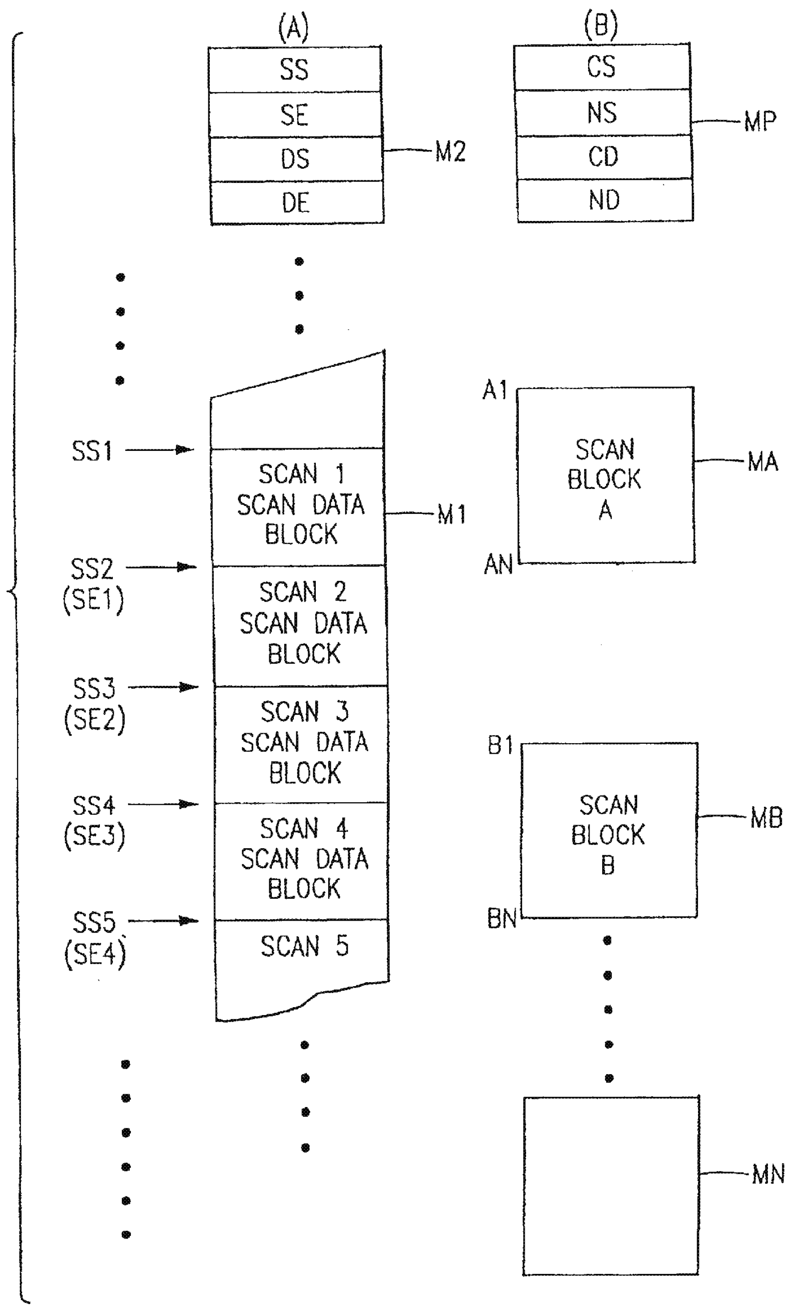

(A)
SCANNING
DECODING
SCAN 1
SCAN 2
SCAN 3
SCAN 4
SCAN 5
SCAN 6
SCAN 7
SCAN 8
DECODE SCAN 1
DECODE SCAN 2
DECODE SCAN 3
DECODE SCAN 4
DECODE SCAN 5
DECODE SCAN 6
DECODE SCAN 7
(B)
SCANNING
DECODING
DECODE SCAN 1
DECODE SCAN 2
DECODE SCAN 3
DECODE SCAN 4
(C)
SCANNING
DECODING
DECODE SCAN 1
DECODE SCAN 2
DECODE SCAN 5
DECODE SCAN 7
(D)
SCANNING
DECODING
SCAN 1 (MEM A)
SCAN 2 (MEM B)
SCAN 3 (MEM B)
SCAN 4 (MEM A)
SCAN 5 (MEM A)
SCAN 6 (MEM B)
SCAN 7 (MEM B)
SCAN 8 (MEM A)
Ts0
Ts1
Ts2
DECODE SCAN 1 (MEMORY A)
DECODE SCAN 3 (MEMORY B)
DECODE SCAN 5 (MEMORY A)
DECODE SCAN 7 (MEMORY B)
(E)
SCANNING
DECODING
SCAN 1 (MEM A)
SCAN 2 (MEM B)
SCAN 3 (MEM C)
SCAN 4 (MEM A)
SCAN 5 (MEM C)
SCAN 6 (MEM B)
SCAN 7 (MEM C)
SCAN 8 (MEM A)
DECODE SCAN 1 (MEMORY A)
DECODE SCAN 2 (MEMORY B)
DECODE SCAN 4 (MEMORY A)
DECODE SCAN 6 (MEMORY B)

FIG.13

FIG.14


(A)
SS
SE
DS
DE
M2
(B)
CS
NS
CD
ND
MP
SS1
SS2
(SE1)
SS3
(SE2)
SS4
(SE3)
SS5
(SE4)
SCAN 1
SCAN DATA
BLOCK
SCAN 2
SCAN DATA
BLOCK
SCAN 3
SCAN DATA
BLOCK
SCAN 4
SCAN DATA
BLOCK
SCAN 5
M1
A1
AN
SCAN
BLOCK
A
MA
B1
BN
SCAN
BLOCK
B
MB
MN

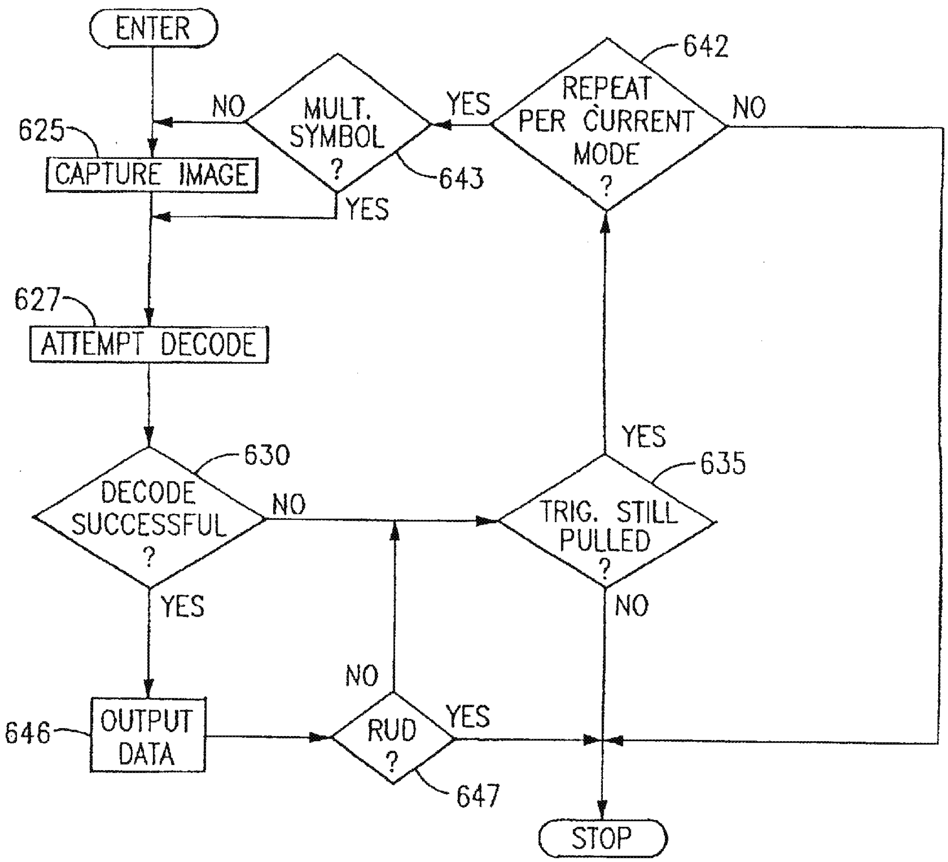
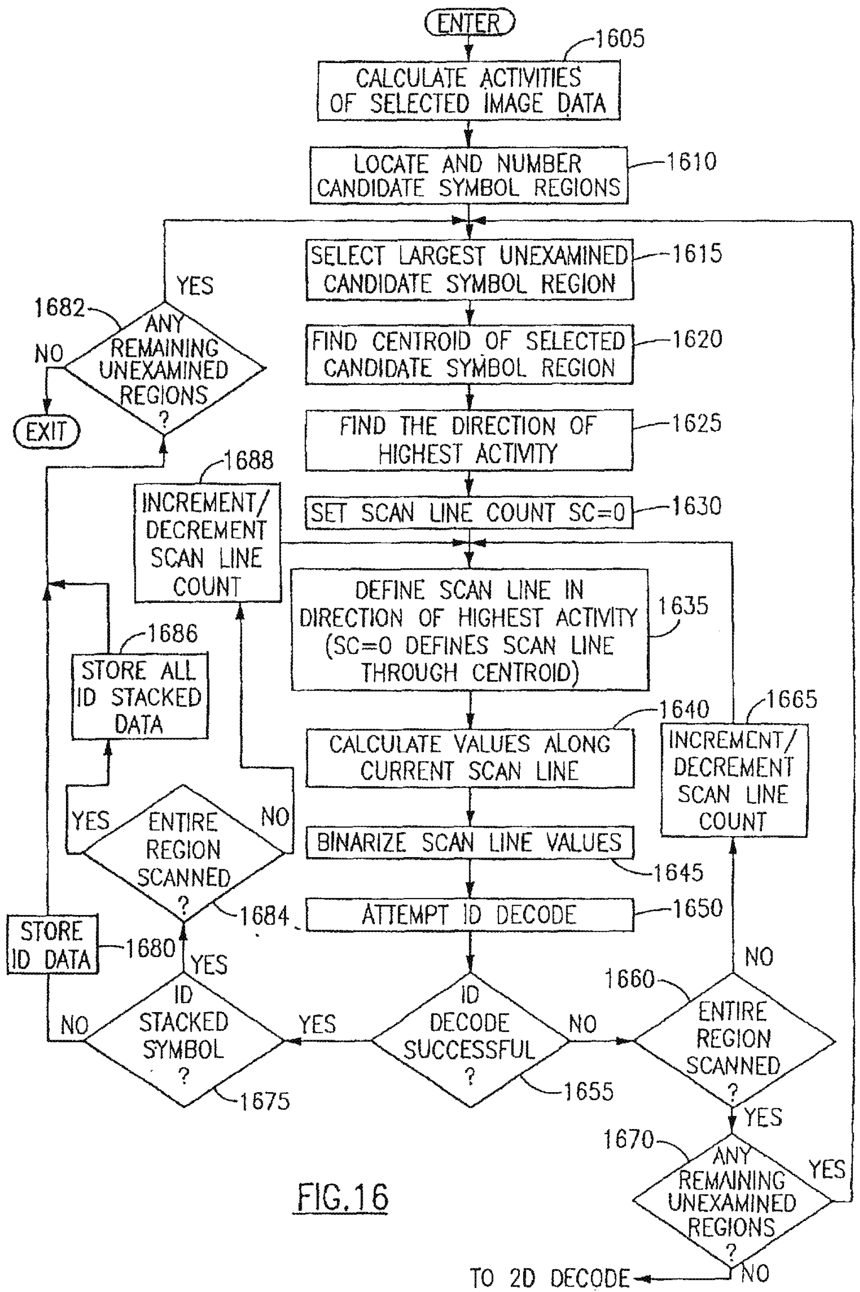

ENTER
625
CAPTURE IMAGE
NO
MULT. SYMBOL ?
643
YES
YES
642
REPEAT PER CURRENT MODE ?
NO
627
ATTEMPT DECODE
630
DECODE SUCCESSFUL ?
NO
YES
YES
635
TRIG. STILL PULLED ?
NO
646
OUTPUT DATA
NO
RUD ?
YES
647
STOP

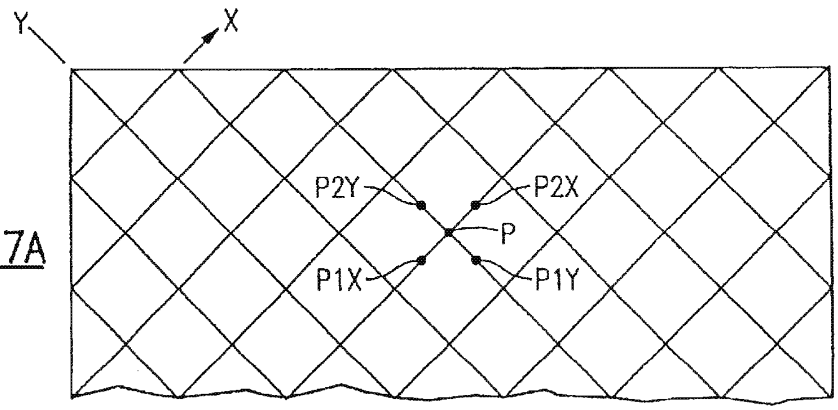
FIG.15



ENTER
1605
CALCULATE ACTIVITIES OF SELECTED IMAGE DATA
LOCATE AND NUMBER CANDIDATE SYMBOL REGIONS
1610
SELECT LARGEST UNEXAMINED CANDIDATE SYMBOL REGION
1615
FIND CENTROID OF SELECTED CANDIDATE SYMBOL REGION
1620
FIND THE DIRECTION OF HIGHEST ACTIVITY
1625
SET SCAN LINE COUNT SC=0
1630
DEFINE SCAN LINE IN DIRECTION OF HIGHEST ACTIVITY (SC=0 DEFINES SCAN LINE THROUGH CENTROID)
1635
CALCULATE VALUES ALONG CURRENT SCAN LINE
1640
BINARIZE SCAN LINE VALUES
1645
ATTEMPT ID DECODE
1650
ID DECODE SUCCESSFUL ?
1655
NO
YES
ENTIRE REGION SCANNED ?
1660
NO
YES
INCREMENT/ DECREMENT SCAN LINE COUNT
1665
ANY REMAINING UNEXAMINED REGIONS ?
1670
YES
NO
TO 2D DECODE
ID STACKED SYMBOL ?
1675
YES
NO
STORE ID DATA
1680
ENTIRE REGION SCANNED ?
1684
YES
NO
STORE ALL ID STACKED DATA
1686
INCREMENT/ DECREMENT SCAN LINE COUNT
1688
ANY REMAINING UNEXAMINED REGIONS ?
1682
YES
NO
EXIT

FIG.16

FIG.17A



$$A_P = (P2X - P1X)^2 + (P2Y - P1Y)^2$$

FIG.17B

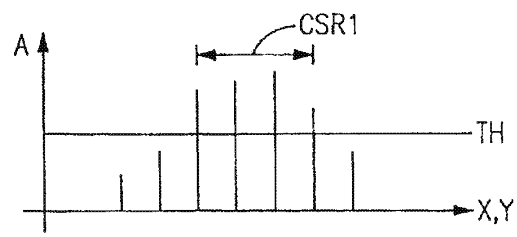
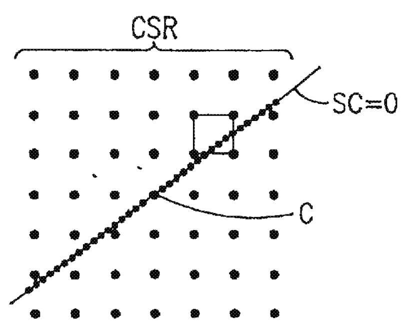


FIG.17C



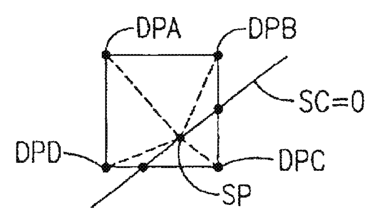
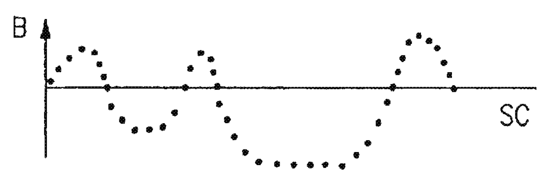


FIG.17D

FIG.17E



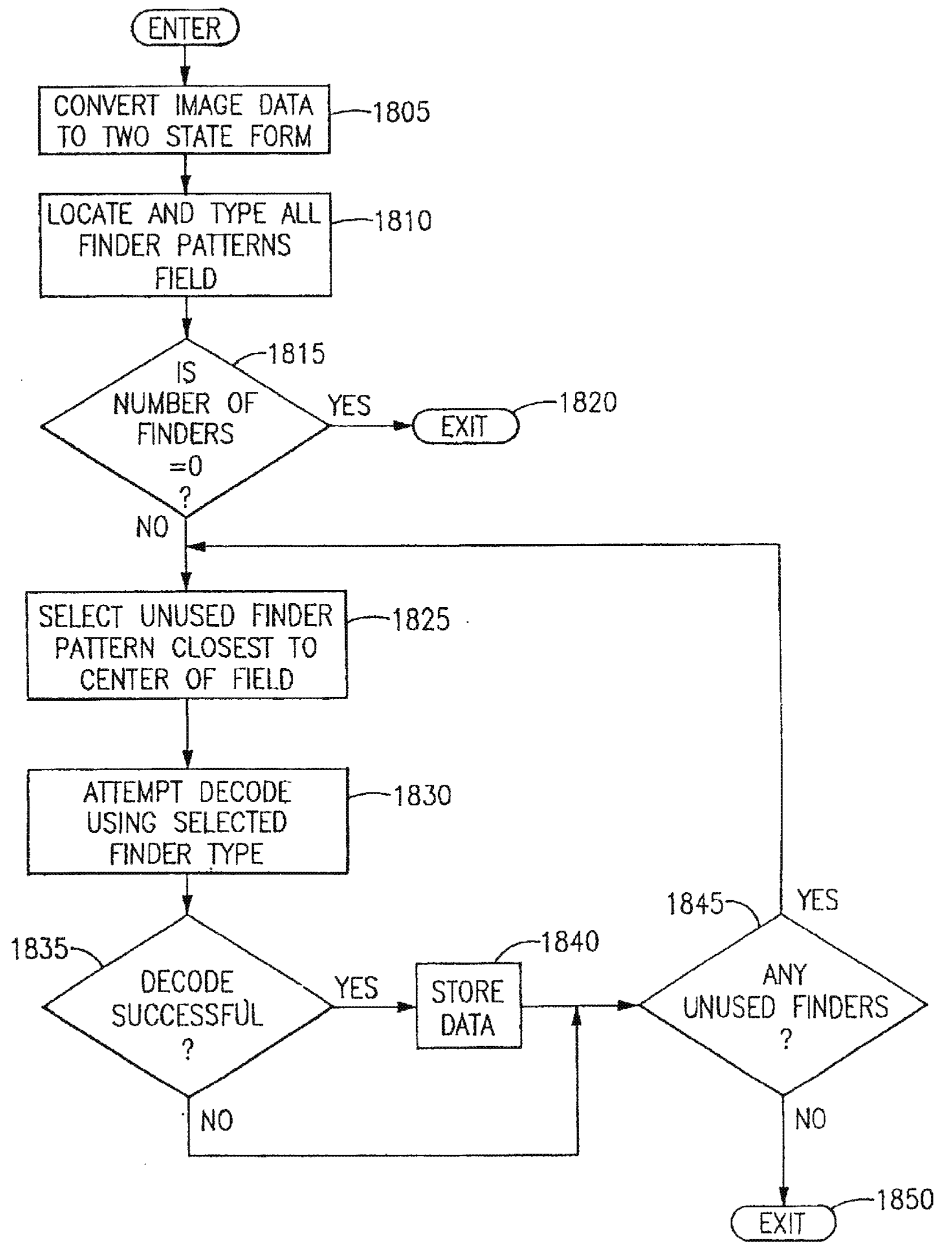

ENTER
CONVERT IMAGE DATA TO TWO STATE FORM
1805
LOCATE AND TYPE ALL FINDER PATTERNS FIELD
1810
IS NUMBER OF FINDERS =0 ?
1815
YES
EXIT
1820
NO
SELECT UNUSED FINDER PATTERN CLOSEST TO CENTER OF FIELD
1825
ATTEMPT DECODE USING SELECTED FINDER TYPE
1830
1835
DECODE SUCCESSFUL ?
YES
STORE DATA
1840
NO
1845
YES
ANY UNUSED FINDERS ?
NO
EXIT
1850

FIG.18

FIG.19A

FIG.19B

FIG.19C

FIG.19D

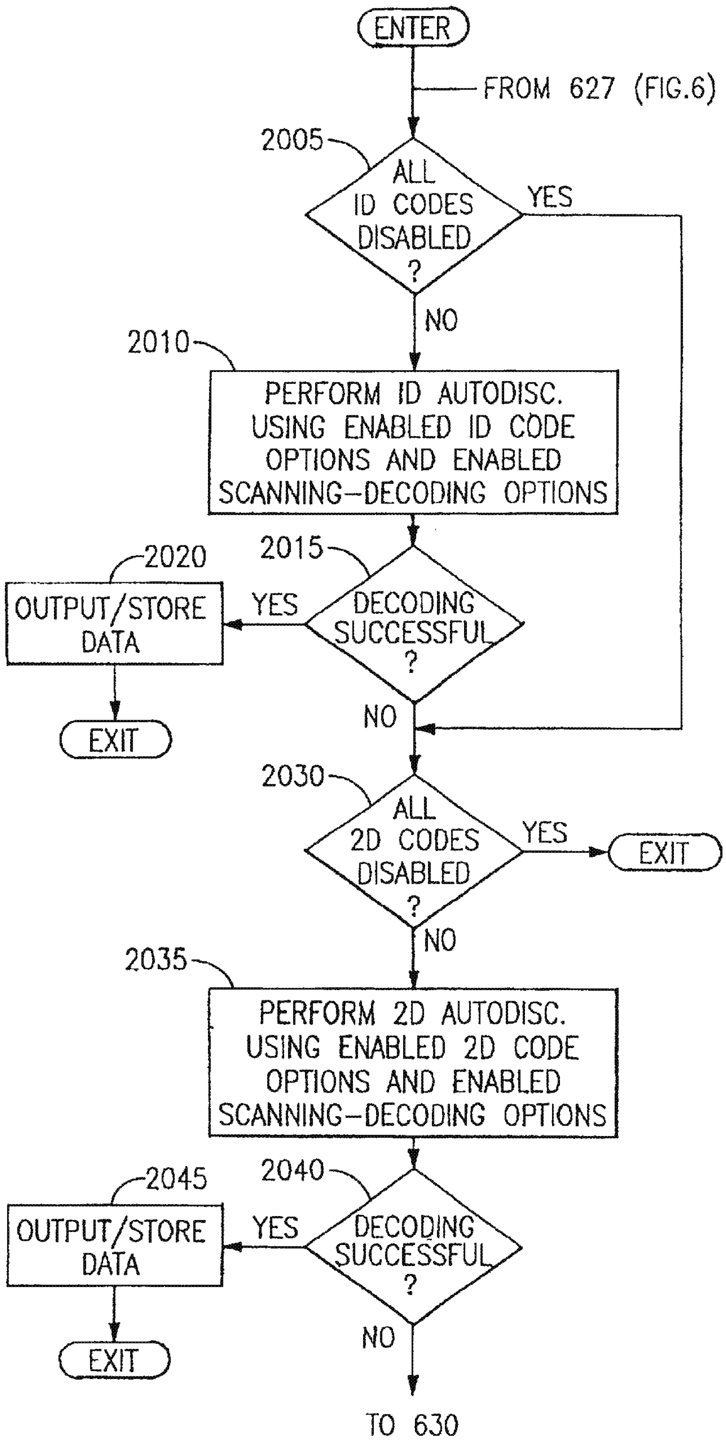

ENTER
FROM 627 (FIG.6)
2005
ALL ID CODES DISABLED ?
YES
NO
2010
PERFORM ID AUTODISC. USING ENABLED ID CODE OPTIONS AND ENABLED SCANNING-DECODING OPTIONS
2020
2015
OUTPUT/STORE DATA
YES
DECODING SUCCESSFUL ?
EXIT
NO
2030
ALL 2D CODES DISABLED ?
YES
EXIT
NO
2035
PERFORM 2D AUTODISC. USING ENABLED 2D CODE OPTIONS AND ENABLED SCANNING-DECODING OPTIONS
2045
2040
OUTPUT/STORE DATA
YES
DECODING SUCCESSFUL ?
EXIT
NO
TO 630

FIG.20

REPROGRAMMABLE OPTICAL READER

CROSS REFERENCES TO RELATED APPLICATIONS

This is a divisional of U.S. patent application No. 09/385,597 filed on Aug. 30, 1999, which is a continuation-in-part of U.S. patent application No. 08/839,020 filed Apr. 23, 1997, which issued as U.S. Pat. No. 5,965,863, which, in turn, is a continuation-in-part of U.S. patent application No. 08/697,913, filed Sep. 3, 1996, which issued as U.S. Pat. No. 5,900,613 on May 4, 1999, the contents of which are relied upon and incorporated herein by reference in its entirety, and the benefit of priority under 35 U.S.C. § 120 is hereby claimed.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to hand held optical reading devices, and is directed more particularly to a hand held optical reading device configured to be programmed with use of a host processor.

2. Description of the Prior Art

One-dimensional optical bar code readers are well known in the art. Examples of such readers include readers of the SCANTEAM® 3000 Series manufactured by Welch Allyn, Inc. Such readers include processing circuits that are able to read one-dimensional (1D) linear bar code symbologies, such as the UPC/EAN code, Code 39, etc., that are widely used in supermarkets. Such 1D linear symbologies are characterized by data that is encoded along a single axis, in the widths of bars and spaces, so that such symbols can be read from a single scan along that axis, provided that the symbol is imaged with a sufficiently high resolution along that axis.

In order to allow the encoding of larger amounts of data in a single bar code symbol, a number of 1D stacked bar code symbologies have been developed, including Code 49, as described in U.S. Pat. No. 4,794,239 (Allais), and PDF417, as described in U.S. Pat. No. 5,340,786 (Pavlidis, et al). Stacked symbols partition the encoded data into multiple rows, each including a respective 1D bar code pattern, all or most all of which must be scanned and decoded, then linked together to form a complete message. Scanning still requires relatively high resolution in one dimension only, but multiple linear scans are needed to read the whole symbol.

A third class of bar code symbologies, known as two dimensional (2D) matrix symbologies, have been developed which offer orientation-free scanning and greater data densities and capacities than their 1D counterparts. Two-dimensional matrix codes encode data as dark or light data elements within a regular polygonal matrix, accompanied by graphical finder, orientation and reference structures. When scanning 2D matrix codes, the horizontal and vertical relationships of the data elements are recorded with about equal resolution.

In order to avoid having to use different types of optical readers to read these different types of bar code symbols, it is desirable to have an optical reader that is able to read symbols of any of these types, including their various subtypes, interchangeably and automatically. More particularly, it is desirable to have an optical reader that is able to read all three of the above-mentioned types of bar code symbols, without human intervention, i.e., automatically. This in turn, requires that the reader have the ability to

automatically discriminate between and decode bar code symbols, based only on information read from the symbol itself. Readers that have this ability-are referred to as "autodiscriminating" or having an "autodiscrimination" capability.

If an autodiscriminating reader is able to read only 1D bar code symbols (including their various subtypes), it may be said to have a 1D autodiscrimination capability. Similarly, if it is able to read only 2D bar code symbols, it may be said to have a 2D autodiscrimination capability. If it is able to read both 1D and 2D bar code symbols interchangeably, it may be said to have a 1D/2D autodiscrimination capability. Often, however, a reader is said to have a 1D/2D autodiscrimination capability even if it is unable to discriminate between and decode 1D stacked bar code symbols.

Optical readers that are capable of 1D autodiscrimination are well known in the art. An early example of such a reader is the Welch Allyn SCANTEAM® 3000, manufactured by Welch Allyn, Inc.

Optical readers, particularly hand held optical readers, that are capable of 1D/2D autodiscrimination are less well known in the art, since 2D matrix symbologies are relatively recent developments. One example of a hand held reader of this type which is based on the use of an asynchronously moving 1D image sensor, is described in copending, commonly assigned U.S. Pat. Appl. No. 08/504,643, now U.S. Pat. No. 5,773,806, which application is hereby expressly incorporated herein by reference. Another example of a hand held reader of this type which is based on the use of a stationary 2D image sensor, is described in copending, commonly assigned U.S. patent application Ser. No. 08/914,883, now U.S. Pat. No. 5,942,741, which is also hereby expressly incorporated herein by reference.

Optical readers, whether of the stationary or movable type, usually operate at a fixed scanning rate. This means that the readers are designed to complete some fixed number of scans during a given amount of time. This scanning rate generally has a value that is between 30 and 200 scans/sec for 1D readers. In such readers, the results of successive scans are decoded in the order of their occurrence.

Prior art optical readers operate relatively satisfactorily under conditions in which the data throughput rate, or rate at which data is scanned and decoded, is relatively low. If, for example, the scanning rate is relatively low and/or the data content of the bar code or other symbol is relatively small, i.e., the scanner is operating under a relatively light decoding load, the decoding phase of the reading process can be completed between successive scans. Under these conditions scan data can be accurately decoded without difficulty.

Readers of the above-described type have the disadvantage that, if they are operated under relatively heavy decoding loads, i.e., are required to rapidly scan symbols that have a relatively high data content, the tracking relationship or synchronism between the scanning and decoding phases of the reading process will break down. This is because under heavy decoding loads the decoding phase of a read operation takes longer than the scanning phase thereof, causing the decoding operation to lag behind the scanning operation. While this time lag can be dealt with for brief periods by storing the results of successive scans in a scan memory and decoding the results of those scans in the order of their occurrence when the decoder becomes available, it cannot be dealt with in this way for long. This is because, however large the scan memory, it will eventually overflow and result in a loss of scan data.

One set of solutions to the problem of maintaining the desired tracking relationship between the scanning and decoding phases of the reading process is described in previously mentioned copending U.S. patent application Ser. No. 08/914,883, now U.S. Pat. No 5,942,741. Another set of solutions to the problem of maintaining the desired tracking relationship between the scanning and decoding phases of the reading process is described in U.S. Pat. No. 5,463,214, which issued on the parent application of the last mentioned copending patent application.

Generally speaking, the latter of these two sets of solutions to the above-discussed tracking problem involves the suspension of scanning for brief periods in order to assure that the scanning process does not pull too far ahead of the decoding process. The former of these two sets of solutions to the above-discussed tracking problem, on the other hand, involves the skipping over of one or more sets of scan data, in favor of more current scan data, if and to the extent necessary for tracking purposes, in combination with the use of two or more scan data memories to minimize the quantity of scan data that is skipped.

In the post, no consideration has been given to accomplishing scan-decode tracking in conjunction with 1D/2D autodiscrimination, i.e., as cooperating parts of a single coordinated process. This is in spite of the fact that the 1D/2D autodiscrimination is known to involve heavy decoding loads of the type that give rise to tracking problems. Thus, a need has existed for an optical reader that combines a powerful tracking capability with a powerful 1D/2D autodiscrimination capability.

As new and/or improved 1D and 2D bar code symbologies, and as additional 1D and 2D decoding programs come into widespread use, previously built optical readers may or may not be able to operate therewith. To the extent that they cannot operate therewith, such previously built optical readers will become increasingly obsolete and unusable.

In the past, the problem of updating optical readers to accommodate new bar code symbologies and/or new decoding programs has been dealt with by manually reprogramming the same. One approach to accomplishing this reprogramming is to reprogram a reader locally, i.e., on-site, by, for example, replacing a ROM chip. Another approach to accomplishing this reprogramming is to return it to the manufacturer or his service representative for off-site reprogramming. Because of the expense of the former and the time delays of the latter, neither of these approaches may be practical or economical.

The above-described problem is compounded by the fact that, if an optical reader is not equipped to operate as a tracking reader, it may not be possible to reprogram it to use an autodiscrimination program that is designed to be executed in conjunction with tracking. This is because the autodiscrimination program may include steps that require the tracking feature to prevent data from overflowing the scan memory and being lost. Alternatively, the scan rate may be decreased, although this reduction will adversely affect performance when low data content symbols are read. Thus, a need has existed for an optical reader that can be reprogrammed economically in a way that allows it to realize the full benefit of the 1D/2D autodiscrimination and tracking features, among others.

SUMMARY OF INVENTION

A programmable optical reader in one embodiment can include a program loading comonent and a program execution component operative to execute an externally generated program, whereby executing the externally generated program includes replacing a portion of the optical reader program. A programmable optical reader in another embodiment can include a two-dimensional image sensor, an image frame memory storing two-dimensional electronic images, and can be configured to be reprogrammed by any one of receipt of reprogramming data from a local host processor or receipt of programming data from an external remote off-site processor.

DESCRIPTION OF THE DRAWINGS

Other objects and advantages will be apparent from the following description and drawings, in which:

FIG. **1** is a block diagram of an embodiment of the reading apparatus which is generic to reading apparatuses which utilize 1D and 2D image sensors;

FIGS. **2** and **3** are block diagrams of embodiments of the reading apparatus of the invention which utilize 2D and 1D image sensors, respectively;

FIGS. **4**A, **4**B, and **4**C are oblique or partially cutaway views of the 2D reading apparatus of FIG. **2**;

FIGS. **4**D, **4**E, and **4**F are oblique or partially cutaway views of an alternative embodiment of the reader apparatus of FIG. **2**;

FIGS. **4**G, **4**H, and **4**I are oblique or partially cutaway views of another alternative embodiment of the reader apparatus of FIG. **2**;

FIGS. **5**A, **5**B, and **5**C are oblique or partially cutaway views of the 1D reading apparatus of FIG. **3**;

FIG. **6**A is a flow chart of the main program of the reading apparatus;

FIG. **6**B is a flow chart of a modified main program of the reading apparatus;

FIG. **7**A shows the structure of one embodiment of a menu word or message suitable for use with the program of FIG. **6**;

FIGS. **7**B and **7**C are tables showing examples of the usages to which various parts of the menu word of FIG. **7**A may be put;

FIG. **8** is a flow chart of the menu routine shown in FIG. **6**;

FIGS. **8**A–**8**D are examples of option symbol selection charts which may be used with the menuing feature;

FIG. **9** is a block diagram of a typical system with which the reading apparatus may be used;

FIG. **10**A is a flow chart of a loading routine suitable for use;

FIG. **10**B is a flow chart of a reprogramming routine suitable for use;

FIG. **11**A is a flow diagram illustrating a primary program for a host processor configured for reprogramming of, and for other interactions with an optical reader;

FIG. **11**B is a flow diagram illustrating a subprogram for reprogramming an optical reader in communication with a host processor;

FIG. **11**C is a memory map for a memory space having stored thereon an operating program comprising a main program and a parameter table;

FIG. **11**D is a flow diagram for a subprogram executed by a host processor for editing a parameter table;

FIG. **11**E illustrates an exemplary parameter configuration screen;

FIG. **11**F illustrates a flow diagram executed by a host processor for simulating the results of applying editing commands to a decoded message.

FIG. **12** is a timing diagram which shows the scanning/decoding relationship used by the prior art;

FIGS. **13**A through **13**E are timing diagrams which illustrate various ones of the tracking relationships made possible;

FIG. **14** shows examples of memory structures that may be used in implementing the tracking relationships shown in FIGS. **13**A through **13**E;

FIG. **15** is a simplified flow chart which illustrates the "Repeat Until Done", "Repeat Until Stopped", and "One Shot" scanning-decoding modes;

FIG. **16** is a flow chart of one embodiment of the 1D portion of the autodiscrimination program;

FIGS. **17**A through **17**E are drawings which facilitate an understanding of the flow chart of FIG. **16**;

FIG. **18** is a flow chart of one embodiment of the 2D portion of the autodiscrimination process;

FIGS. **19**A through **19**D show representative bar code symbols of types that may be decoded by the reading apparatus; and

FIG. **20** is a flow chart that illustrates the effect of the code options of the autodiscrimination process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** there is shown a block diagram of an optical reader **10**. As will be explained more fully later, FIG. **1** shows the basic structures that together comprise the general form of an optical reader that is suitable for use and is generic to optical readers that use 1D image sensors and to optical readers that use 2D image sensors. Similarly, FIG. **2** shows the basic structures that together comprise the general form of optical readers that use 2D image sensors. Finally, FIG. **3** shows the basic structures that together comprise the general form of optical readers that use 1D image sensors. It will be understood that, except where specifically limited to readers having 2D or 1D image sensors, the present description refers generically to readers of any of the types shown in FIGS. **1**, **2**, and **3**.

Referring first to FIG. **1**, the optical reader includes an illumination assembly **20** for illuminating a target object T, such as a 1D or 2D bar code symbol, and an imaging assembly **30** for receiving an image of object T and generating an electrical output signal indicative of the data optically encoded therein. Illumination assembly **20** may, for example, include an illumination source assembly **22**, such as one or more LEDs, together with an illuminating optics assembly **24**, such as one or more reflectors, for directing light from light source **22** in the direction of target object T. Illumination assembly **20** may be eliminated, if ambient light levels are certain to be high enough to allow high quality images of object T to be taken. Imaging assembly **30** may include an image sensor **32**, such as a 1D or 2D CCD, CMOS, NMOS, PMOS, CID or CMD solid state image sensor, together with an imaging optics assembly **34** for receiving and focusing an image of object T onto image sensor **32**. The array-based imaging assembly shown in FIG. **2** may be replaced by a laser array or laser scanning based imaging assembly comprising a laser source, a scanning mechanism, emit and receive optics, a photodetector and accompanying signal processing circuitry.

Optical reader **10** of FIG. **1** also includes programmable control means **40** which preferably comprises an integrated circuit microprocessor **42** and an application specific integrated circuit or ASIC **44**. Processor **42** and ASIC **44** are both programmable control devices which are able to receive, output and process data in accordance with a stored program stored in either or both of a read/write random access memory or RAM **45** and an erasable read only memory or EROM **46**. Processor **42** and ASIC **44** are also both connected to a common bus **48** through which program data and working data, including address data, may be received and transmitted in either direction to any circuitry that is also connected thereto. Processor **42** and ASIC **44** differ from one another, however, in how they are made and how they are used.

More particularly, processor **42** is preferably a general purpose, off-the-shelf VLSI integrated circuit microprocessor which has overall control of the circuitry of FIG. **1**, but which devotes most of its time to decoding image data stored in RAM **45** in accordance with program data stored in EROM **46**. Processor **44**, on the other hand, is preferably a special purpose VLSI integrated circuit, such as a programmable logic or gate array, which is programmed to devote its time to functions other than decoding image data, and thereby relieve processor **42** from the burden of performing these functions.

The actual division of labor between processors **42** and **44** will naturally depend on the type of off-the-shelf microprocessors that are available, the type of image sensor which is used, the rate at which image data is output by imaging assembly **30**, etc. There is nothing in principle, however, that requires that any particular division of labor be made between processors **42** and **44**, or even that such a division be made at all. This is because special purpose processor **44** may be eliminated entirely if general purpose processor **42** is fast enough and powerful enough to perform all of the functions contemplated. It will, therefore, be understood that neither the number of processors used, nor the division of labor therebetween, is of any fundamental significance.

With processor architectures of the type shown in FIG. **1**, a typical division of labor between processors **42** and **44** will be as follows. Processor **42** is preferably devoted primarily to the tasks of decoding image data, once such data has been stored in RAM **45**, handling the menuing options and reprogramming functions, and providing overall system level coordination. Processor **44** is preferably devoted primarily to controlling the image acquisition process, the A/D conversion process and the storage of image data, including the ability to access memories **45** and **46** via a DMA channel. Processor **44** may also perform many timing and communication operations. Processor **44** may, for example, control the illumination of LEDs **22**, the timing of image sensor **32** and an analog-to-digital (A/D) converter **36**, the transmission and reception of data to and from a processor external to reader **10**, through an RS-232 (or other) compatible I/O device **37** and the outputting of user perceptible data via an output device **38**, such as a beeper, a good read LED and/or a display **39** which may be, for example, a liquid crystal display. Control of output, display and I/O functions may also be shared between processors **42** and **44**, as suggested by bus driver I/O and output/display devices **37'** and **38'** or may be duplicated, as suggested by microprocessor serial I/O ports **42**A and **42**B and I/O and display devices **37"** and **38'**. As explained earlier, the specifics of this division of labor is of no significance.

Referring to FIG. **2**, there is shown a block diagram of an optical reader which is similar to that of FIG. **1**, except that it includes optical and/or electrical assemblies and circuits that are specifically designed for use with a 2D image sensor.

Accordingly, the optical and electrical assemblies and components of FIG. **2** are labeled with the same numbers used in FIG. **1**, except for the addition of the suffix "-2". For example, image sensor **32-2** of FIG. **2** is a 2D image sensor which corresponds to generic image sensor **32** of FIG. **1**, imaging optics assembly **34-2** of FIG. **2** is a 2D imaging optics assembly which corresponds to generic imaging optics assembly **34** of FIG. **1**, and so on. In other words, corresponding elements of FIGS. **1** and **2** have corresponding functions, although they may have different shapes and part numbers. Provided that these differences are taken into account, however, the description of the reader of FIG. **1** is equally applicable to the reader of FIG. **2**, and will not be repeated herein.

One specific practical example of an optical reader of the type shown in FIG. **2** may be constructed using the particular commercially available solid-state integrated circuits listed in the following component table:

COMPONENT TABLE-FIG. 2

Block Diagram Item	Manufacturer/Part Number
Image Sensor 32-2	VVL 1060B+
Prog. Gate Array 44-2	Actel 814V40A
Microprocessor 42-2	IDT 3081
EROM 46-2	Intel 28F400VB-B60
RAM 45-2	Toshiba TC51V4265DFT-60

Referring to FIG. **3**, there is shown a block diagram of an optical reader which is also similar to that of FIG. **1**, except that it includes optical and/or electrical assemblies and circuits that are specifically designed for use with a 1D image sensor. Accordingly, the optical and electrical assemblies and components of FIG. **3** are labeled with the same numbers used in FIG. **1**, except for the addition of the suffix "-3". For example, image sensor **32-3** of FIG. **3** is a 1D image sensor which corresponds to generic image sensor **32** of FIG. **1**, imaging Optics assembly **34-3** of FIG. **3** is a 1D imaging optics assembly which corresponds to generic imaging optics assembly **34** of FIG. **1**, and so on. Provided that these differences are taken into account, however, the description of the reader of FIG. **1** is equally applicable to the reader of FIG. **3**, and will not be repeated herein.

One specific practical example of an optical reader of the type shown in FIG. **3** may be constructed using the particular solid-state circuits listed in the following component table:

COMPONENT TABLE-FIG. 3

Block Diagram Item	Manufacturer/Part Number
Image Sensor 32-3	Toshiba 1201
Prog. Gate Array 44-3	Welch Allyn 21203276-01
Microprocessor 42-3	Motorola HC11
EROM 46-3	Atmel AT 29C257
RAM 45-3	Sony CXK 5864-BM-10LL

Significantly, the above-mentioned structural correspondences between FIGS. **1**, **2**, and **3** should not be confused with the types of symbols that may be read thereby. More particularly, the 2D embodiment of FIG. **2** may be used to scan and decode both 1D and 2D bar code symbols. This is because both types of symbols can be imaged by a 2D image sensor. Similarly, the 1D embodiment of FIG. **3** may also be used to scan and decode both 1D and 2D bar code symbols. This is because a 1D image sensor may be used to image a 2D bar code symbol, provided that it is physically moved thereacross during the course of a scan. Because imaging of the latter type is described in detail in copending U.S. patent application No. 08/504,643, now U.S. Pat. No. 5,773,806, which has been incorporated by reference herein, that type of imaging assembly will not be discussed again in full herein.

The reader structures shown in FIG. **2** are preferably supported on one or more printed circuit boards (not shown) that are, in turn, supported within a housing.

Examples of types of housings which may be employed to house elements of the reader apparatus shown in FIG. **2** are shown in FIGS. **4**A–**4**I. FIGS. **4**A–**4**C show a first exemplary housing **50-2-1**, FIGS. **4**D–**4**F show a second exemplary housing **50-2-2**, while FIGS. **4**G–**4**I show a third exemplary housing **50-2-3**. Housings **50-2-1**, **50-2-2**, and **50-2-3** are preferably shaped so as to fit comfortably into a human hand, and to include a finger actuatable trigger, **52-2-1**, **52-2-2**, **52-2-3**. Housing **50-2-3** is shown as having an auxiliary trigger **52-2-3'** which may supplement or replace trigger **52-2-3**. Housings **50-2-1** and **50-2-2** have extending therefrom multiconductor cable or tether **54-2-1**, **54-2-2**, for providing communication with a local host processor, whereas **50-2-3** housing has extending therefrom an antenna **55-2-3** for providing a communication with a local host processor. It is seen further that housings **50-2-2** and **50-2-3** have incorporated therein displays **56-2-2**, **56-2-3**, for displaying information to a user, and a keyboard **58-2-2**, **58-2-3**, for inputting data and commands to processor **40**.

FIGS. **5**A–**5**C show a housing **50-3** suitable for housing a 1D reader apparatus of the type described with reference to FIG. **3**. Housing **50-3** includes a finger-actuatable trigger **52-3** and has extending therefrom a cable **54-3** for providing communication with a local host processor. Although not shown as containing such features, it is understood that housing **50-3** could readily be modified to include a display and a keyboard similar to those of 2D reader housings **50-2-2** and **50-2-3**.

Main Program

The overall operation of the reader of FIG. **1** will now be described with reference to the flow chart of FIG. **6**A. As will be explained more fully presently, FIG. **6**A comprises a high level flow chart which illustrates the preferred embodiment of the main program of a reader which uses the apparatus and method. By "main program" is meant the program that illustrates the relationships between the major subdivisions or subroutines that together implement the above-described features. It also means the program that illustrates the overall flow and sequence of operations that are responsible for the advantages produced. Because FIG. **6**A depicts the operation of two processors **42** and **44**, however, operations that appear to be occurring sequentially may actually be occurring "simultaneously". Processor **44** may, for example, be imaging and storing newly scanned blocks of image data in RAM **45** while processor **42** is decoding blocks of image data that were stored in RAM **45** during earlier scans. This is possible because the two processors are operating in different memory spaces, in different time slots, or under the common control of a bus arbitration device. As a result, while the processors can never use the same memory or address space at the same time for conflicting purposes, they can be made to execute their respective programs sufficiently cooperatively and contemporaneously that they are effectively operating simultaneously. It is in this sense that the word "simultaneous" will be used herein.

Referring to FIG. **6**A, the main program begins with block **605** which causes the reader to wait in a low power state until trigger **52** is pulled. When the trigger is pulled, the processor is directed to block **610**, which causes it to power up and initialize the reader hardware, including the ASIC, the DMA channel and the I/O devices, among others. The processor is then directed to blocks **615** and **620** which cause it to define the image data memory space that will be used (block **615**) and to initialize the reader with the default values of the operating parameters stored in the parameter table thereof (block **620**).

The parameter table, which is preferably stored in EROM **46**, specifies the values of the parameters that define the mode in which the reader will operate. Examples of these parameters include the size and the frame rate of the image sensor, the codes that will be enabled during autodiscrimination, the I/O communication protocols, beeper pitch or volume, among others. The default values of these parameters are those which will be used if the user or an externally generated reprogramming command does not specify other values, and correspond to a combination of parameters which are suitable for use under most operating conditions. The different parameters that may be used, and the affect that they have on the operation of the reader will be discussed in detail later.

After the reader has been initialized, the processor proceeds to blocks **625** and **627**, which call for it to capture and attempt to decode an image of the target symbol. This involves the performance of a number of related steps, the particulars of which are determined by the parameters of the parameter table. Included among these steps are a scanning subroutine which specifies the address space or spaces in which scan data will be stored and whether scanning is to be continuous (e.g., at a full video rate, such as 30 frames per second), or discontinuous (e.g., with pauses related to the current state of the trigger). The operation of the decoding routine, which is executed in a user or factory selectable relationship to the scanning routine, is governed by parameters which control the codes which are enabled for processing as a part of the autodiscrimination process, whether decoding is to be continuous or discontinuous, etc. As will be explained more fully later, permitted combinations of scanning and decoding parameters together define the scanning-decoding relationships or modes which the reader will use.

After exiting block **627**, the processor is directed to block **630** which, if the decoding attempt was not successful, is directed back to block **625** unless the trigger has been released (block **635**) or unless reprogramming request has been received (block **640**), or unless a stop or no-repeat request is called for by the current operating mode of the reader (block **642**). The loop defined by blocks **625**–**642** will be the path repeatedly followed by the processor when autodiscrimination sequences are performed unsuccessfully, and no menuing or programming changes are called for, and no stop request is in effect. If this loop is interrupted by the user's release of the trigger, or by a successful decode, or by a reprogram request, or by a stop request, the reader will be directed by block **635** to stop and wait in a low power state until further processing is called for.

In the above-described loop, block **642** serves the function of stopping the repetitive scanning and decoding of the target symbol in those scanning-decoding modes or under those conditions in which a repetition of scanning and/or decoding is not called for. In the One Shot mode, for example, scanning and decoding are discontinued after one decoding attempt, whether or not that attempt is successful, without regard to the state of the trigger. Similarly, in the Repeat Until Stopped mode, scanning and decoding may be discontinued either by command, via block **642**, or by the release of the trigger via block **635**. Thus, block **642** comprises at least a part of the means by which the reader gives effect to the scanning-decoding parameters of the parameter table.

If block **630** indicates that the last decoding attempt was successful, the processor is directed to a block **645** which calls for a determination of whether the result of the decoding indicates that the decoded symbol was or was not a menu symbol. This determination may be made on the basis of results of the decoding, because all menu symbols are encoded with data that identifies them as such during decoding. If the decoded symbol is not a menu symbol, it is known that the symbol contained data that is to be output by the reader. In the latter event, the processor is directed to block **646**, which causes it to output the data and, proceed to block **647**.

Block **647**, like block **642**, comprises part of the means by which the reader gives effect to the scanning-decoding modes called for by the parameter table. In particular, if decoding is successful (block **630**) and has been output (block **646**), block **647** discontinues scanning and decoding if the Repeat Until Done mode is in effect. If any other mode is in effect, scanning and decoding will continue unless blocks **635**, 2D **640** or **642** call for a different result.

If the decoded symbol is a menu symbol, block **645** directs the processor to perform the menuing routine called for by block **660** before returning to block **635**. As will be explained more fully later in connection with FIG. **8**, the latter routine enables the user to command the reader to perform any of a variety of different tasks, several of which include making user specified changes to the parameter table, thereby changing the operating mode of the reader, and the performance of any of a variety of user specified vector processing routines that do not change the parameter table. Once either of the latter tasks has been performed, the reader is directed to block **635**, which causes it to capture and attempt to decode another image, in accordance with the parameters indicated by the parameter table, unless instructed to the contrary by blocks **635**, **640** or **642**. Optionally, the execution of menu routine **660** may be followed by a direction back to block **647**, as indicated by dotted line **648**, and the resultant discontinuation of scanning and decoding, if the reader is in its Repeat Until Done mode.

While reprogramming request block **640** has been described as being located between blocks **635** and **625**, it actually preferably represents an externally generated interrupt request that may occur at any time that the reader is operating. Such a request may, for example, be initiated by a local host processor via one of I/O devices **37**, **37'** or **37"**. It may also be initiated by a remotely located processor, via one of the latter I/O devices, through a suitable transmission line or computer network, as shown in FIG. **9**. However the reprogramming request is initiated, it directs the reader to execute the reprogramming routine called for by block **670**. As will be explained more fully in 2D connection with FIG. **10**A, this routine causes the reader to be reprogrammed, either in whole or in part, thereby changing or updating the manner in which it operates and/or the symbols which it attempts to decode.

Menuing

The menuing feature will now be described with reference to FIGS. **7**A–**7**C, and the menuing flow chart shown in FIG. **8**.

Turning first to FIG. **7**A, there is shown the format for a menu message or word **650** of the type used. This menu word will ordinarily be produced as a result of the decoding of a menu symbol, selected by the user, from a collection of menu symbols printed in a User's Manual supplied with the reader, along with a description of their functions.

Menu word **650** begins with a first one-byte product identification (ID) code field **650-1** that identifies the type and/or model number of the reader. If the decoded product ID code indicates that it is compatible with the menuing program, execution of the menuing program continues normally. If it is not, the processor is caused to exit the menuing routine without making any menu specified changes.

The next field **650-2** of menu word **650** specifies the op code thereof in terms of a number from 0 to 7. This field specifies the operation to be performed by the menu word. The meanings of these different op codes are listed in FIG. **7**C. Among these is op code "0", an op code that specifies some task that does not involve a direct change to the parameter table. Such operations will hereinafter be referred to as "vector processing operations". Exemplary ones of the tasks that may be requested pursuant to op code **0** are listed under headings A**1**–A**4** of FIG. **7**C, which tasks may be specified and differentiated from one another by the data included in the data fields **650-3** through **650-7** which follow op code field **650-2**.

Specifically, the vector processing operations comprise selectable menu routines. Vectors to these routines can be stored in a vector table. The contents of data field **650-3**, "offset", is an index to the vector table relative to the base address thereof. If the offset field includes 10 bits, and only five of these bits are used as an index, then 32 different vector values will be possible. In this case the remaining 5 bits may be used for data.

The vector processing operations are preferably made selectable to a user by including respective menu bar code symbols in tables in the User's Manual of the reader. The user may then select the desired vector routine by imaging the appropriate symbol. The manner in which such a table is used will be described later in connection with FIGS. **8**A–**8**D.

Among the vector processing operations which may be selected under op code **0** are the following. Operation A**1** calls for the reader to output, i.e., display or print, via the local host processor, or via an on-reader LCD display, the identity of the version of the software currently being used by the reader. Operation A**2** calls for the reader to output the current contents of the parameter table. Operation A**3** calls for the reader to output the code options that are enabled, e.g., the types of symbols that the reader is to attempt to decode during the autodiscrimination process and whether or not a "multiple symbols option" has been enabled. Other options may also be defined as desired.

Operation A**4** is a particularly powerful and desirable vector processing operation which causes the printer of the local host processor to print a menu bar code symbol that contains all of the information necessary to instruct another reader how it must be programmed if it is to operate in the same manner as the current reader. This, in turn, enables the user to quickly set up the same (or another) reader to operate in a manner that would otherwise require the user to manually select an entire sequence of parameter table values. If it is used to set up other readers, the process of using such a menuing bar code symbol may be thought of as a "cloning" procedure, since it allows a multiplicity of readers to be identically configured.

The type of bar code symbol in which the parameter table is printed must naturally be in a bar code symbology in which the reader is able to both encode (or write) data and decode (or read) data. Because the parameter table has a data content which may be too high to be encoded in many 1D symbologies, the menu symbol encoding the parameter table is preferably encoded in a 2D bar code symbol. One 2D symbology which is particularly suitable for use in encoding a menu bar code symbol of the subject type is that developed by Welch Allyn, Inc. and referred to as the "Aztec" symbology. The manner in which data is encoded in accordance with the Aztec symbology is described in detail in copending, commonly assigned U.S. Pat. No. 5,591,956, which is hereby expressly incorporated herein by reference.

In addition to op code **0**, menu word **650** also makes available op codes **1**–**7**, as shown in FIG. **7**C. The latter op codes comprise simple commands, each of which specifies a change that is to be made at a particular part of the parameter table, using specified data, if required. Assuming that parameter values are stored as bytes in respective addresses of the memory that are set aside for use as a parameter table, offset field **650-3** will comprise an index to the parameter byte relative to the base address of the table. The data or data mask that is to be used with the specified offset is specified by the data contained in up to four 8 bit data fields **650-4** through **650-7** of menu word **650**.

Referring to FIG. **7**C, for example, op code "1" specifies a "clear" operation. It directs the processor to the byte of the parameter table that is pointed to by the offset field, and uses the content of data field **650-4**, Data **0**, to specify the bit mask that is to be used to specify the bits to be cleared. Op code "6", on the other hand, specifies a load operation. It directs the processor to the byte of the parameter table that is pointed to by the offset field, uses Data **0** as the bit mask for the bits to be changed, and uses Data **1** as the new data for those bits. Because the use of op codes of this type are known to those skilled in the art, the use of these op codes will not be described in detail herein.

The parameter table is used to specify the operating options that are made subject 2D to the control of the user. Representative groups of such options are shown as headings A–E of FIG. **7**B, together with some of the options that may be selected under those headings. One important group of those options are those that are labeled as "code options" under heading B. Under this heading may be found the parameter table addresses that are set aside for use in specifying the enabled/disabled states of the various decoding programs that may be used during the autodiscrimination process. The parameter table addresses corresponding to options B**1** and B**2**, for example, may be set aside for specifying whether all 1D codes or all 2D codes are or are not to be used in an attempt to decode an unknown symbol during autodiscrimination. Similarly, the parameter table address corresponding to option B**3**, may specify a particular bar code symbology, such as MaxiCode, that is to be enabled or disabled, i.e., specify whether the autodiscrimination process is or is not to include an attempt to find a MaxiCode symbol in an image. In addition, the parameter table address corresponding to option B**4** may indicate that after decoding, messages that are longer than a specified maximum length or shorter than a specified minimum length are not to be output. Depending on the application, this Min-Max length option may be applied on a symbology dependent basis, i.e., applied so that it is active with some symbologies, but not with others, or may be applied on a symbology independent basis. Finally, the parameter table address corresponding to option B**5** specifies whether the Multiple Symbols option is or is not to be used. The enablement of this option, which given effect by block **643** of FIG. **6**A, calls for the reader to

attempt to decode more than one symbol in the field of view of the reader without having to acquire multiple images of that field of view. The types of options selected for inclusion under heading B will vary from application to application, and the will be understood not to be restricted to any particular selection of such types.

The inclusion of user selectable code options as part of the menuing process has a significant effect on the overall data throughput rate of the reader, i.e., on the time necessary to decode a symbol whose symbology is not known in advance. If, for example, it is known that none of the symbols to be read during a series of readings comprise 1D symbols of any type, or any subset of 1D symbols such as Codabar, Code 39 or Code 128, code options allow a user to direct that any attempt to decode an unknown symbology according to these symbologies is to be skipped, thereby shortening the total time necessary for the processor to decode the unknown symbol according to the symbology which it does use. This skipping also reduces the chances of a misread. If, on the other hand, it is known that all of the symbols to be read during a series of reading operations are of one type, such as Interleaved **2** of **5**, all 2D decoding programs and all the decoding programs for 1D symbologies other than interleaved **2** of **5** may be disabled, thereby limiting all decoding attempts to a single 1D symbology. Thus, the menuing process allows the autodiscrimination process to be optimized so as to achieve the highest possible data throughput rate.

A second important group of options provided by the menuing process are those that are labeled as "Scanning-Decoding" Options under heading C of FIG. **7**B. Unlike the code options of heading B, the scanning-decoding options of heading C are not concerned with which codes are enabled or disabled, but rather with the relationships which will be allowed to exist between scanning and decoding. The parameter table address corresponding to option C**1**, for example, may be used to specify that the reader operate in a "One Shot" scanning-decoding mode. In this "One Shot" mode the reader will scan and attempt to decode one bar code symbol each time that the trigger is depressed and then stop. The address spaces corresponding to scanning-decoding modes C**2** and C**3**, on the other hand, may be used to specify that the reader operate in a "Repeat Until Done" (RUD) or "Repeat Until Stopped" (RUS) scanning-decoding mode. In these modes, the reader will scan repeatedly and attempt to decode repeatedly until there is a successful decode (RUD), or until requested to stop whether or not there is a successful decode (RUS). Scanning-decoding modes C**1**–C**3** are preferably made user selectable by including suitable menu symbols in the User's Manual.

Also included among the scanning-decoding modes are the tracking modes listed under headings C**4**–C**6** of FIG. **7**B. Of these, the Scan On Demand (SOD) mode C**4**, when enabled, causes decoding to proceed continuously while scanning is started and stopped as necessary to maintain a tracking relationship between scanning and decoding. Skip Scan (SS) scanning-decoding mode C**5**, when enabled, causes the results of older scans to be discarded in favor of more current scans when and as necessary to maintain the desired tracking relationship between scanning and decoding operations. Finally, Decode On Demand (DOD) scanning-decoding mode C**6**, when enabled, causes scanning to proceed continuously while decoding is started or stopped as necessary to maintain a tracking relationship between scanning and decoding. The particular one of these tracking modes that will be used is preferably set during manufacture, based on the amount of image data memory that is present within the reader, and not changed thereafter. There is no reason in principle, however, why tracking options C**4**–C**6** cannot be made user selectable as, for example, by the inclusion of suitable menu symbols in the User's Manual.

The availability of the SOD, SS and DOD tracking modes among the scanning-decoding options that may be selected during the factory programming of the reader is beneficial since it allows the data throughput rate of the reader to be optimized in view of the amount of memory that is available within the reader. At the same time, because operation in all of these modes may be disabled during operation in the One Shot, Repeat Until Done, or Repeat Until Stopped modes, the reader is able to operate in accordance with the non-tracking variants of these modes when such operation is preferred. One condition under which such operation may be preferred is one in which scanning while decoding is slow as a result of the time sharing of a bus. Thus, the reader combines flexibility of use with time-optimized use of the scanning and memory resources of the reader.

As will be explained more fully later, the RUD and RUS modes may be used either with or without one of the above-described tracking modes. This is because repetition is a necessary but not a sufficient precondition to the use of the tracking modes. Accordingly, if the RUD or RUS mode is not used in conjunction with a tracking mode it will comprise a non-tracking mode. If the RUD or RUS mode is used in conjunction with a tracking mode it will comprise a tracking mode.

Other groups of options that are provided by the menuing feature include those that are set aside under headings A, D and E of FIG. **7**B. Of these Communication Options, heading A, is associated with parameter table addresses that correspond to various communication modes that may be used by the reader. Included among these options are A**1**, an option that enables/disables RS-232 communication through an I/O device (such as I/O **37**, **37'**, etc.), A**2** which specifies the baud rate of the selected communications mode, and A**3** which enables/disables the RF link that the reader may use in place of multi-conductor cable **54-2** of FIGS. **4**A–**4**C. Option A**4** is an example of a network option which specifies the type of computer network with which the reader is to operate, in this case ETHERNET, although other types may also be provided for.

Similarly, heading D is associated with parameter table addresses that correspond to various miscellaneous operating options that may be selected by the user. Included among these options are D**1** which enables/disables the beeper and allows the volume thereof to be adjusted, D**2** which enables/disables the use of an aiming LED, and D**3** which enables/disables the provision of aural feedback to the user, among others. An example of a reader which provides aural feedback is described in U.S. Pat. No. 5,420,409.

Heading E is associated with parameter table addresses that correspond to various transmission options that may be selected by the user. Included among these options are E**1** and E**2**, which enable/ disable the outputting of check characters or checksum data with decoded data, and E**3** which enable data edit options such as adding a carriage return and/or a line feed and/or other ASCII characters to the decoding data. Options E**1** and E**2** are useful, for example, in the localization and identification of hardware or software failures during the servicing of the reader. Option E**3** is useful in placing decoded data in a form suitable for use with an application program.

Heading F is associated with parameter table addresses that correspond to various message editing commands for

editing the form of characters in a decoded message. These commands may be, for example, search and replace commands (option F**1**), commands to insert characters (option F**2**), commands to delete characters from a decoded message (option F**3**), or other commands.

Heading G, meanwhile, is associated with parameter table addresses that correspond to commands for adding prefixes or suffixes, of a selectable character length, to a decoded message. Prefixes and suffixes are added to messages so that the host processor can identify the source of, or other characteristics of received messages. Option G**1** allows addition of a prefix to a decoded message while option G**2** allows addition of a suffix to a decoded message.

In view of the foregoing, it will be seen that the menuing process of the invention provides a wide range of user selectable functions and modes that allow the reader to be tailored to a user's specific application and/or preferences. Among these, the code options and the scanning-decoding options in particular, allow a user to reconfigure the operation of the reader in ways that have not heretofore been possible and thereby substantially increase the flexibility and overall data throughput rate of readers.

The manner in which the reader can be updated to accomplish the above-described results will now be described with reference to the flow chart of FIG. **8**, which shows the steps included within menu routine block **660** of FIG. **6**A. The menu routine of FIG. **8** begins with a block **805** which causes the processor to convert the decoded menu symbol message into hexadecimal form. This has the effect of formatting the **30** message so that the fields of the menu word are expressed as pairs of hexadecimal digits. Once this has been done the processor examines the product ID code to verify that it is compatible with the reader being menued. If it is not, the processor is directed to exit the menuing routine and continue scanning. If it is, the processor is directed to block **810** which distinguishes those menu messages which contain op codes from those which contain numerical data but no op codes. If there is no op code, the processor is directed to block **815**, which causes it to collect in an accumulator all of the digits of the message for later use before proceeding to block **850**. An example of numerical data without an op code comprises the minimum or maximum length of the messages that are to be output under code option B**4**.

If the menu message contains an op code, and the op code is other than 0, the processor is directed, via block **820**, to a block **825**. The latter block causes it to make the parameter table changes called for by the op code and the associated offset and data fields, sets a "flash" flag to indicate that changes have been made and then proceeds to block **850**. This has the effect of implementing the user selected changes in the menuing options discussed previously in connection with FIG. **7**B. Such changes will ordinarily be made in a copy of the parameter table that is stored in RAM **45**, and then later transferred to EROM **46**.

If the menu message contains an op code of 0, the processor is directed, via block **820**, to a block **830**. The latter block causes the processor to perform the vector processing operation indicated by the remainder of the message. This operation will comprise one of the operations discussed previously in connection with items A**1**–A**4** of FIG. **7**C, among others, before proceeding to block **850**.

In view of the foregoing, it will be seen that, when the processor arrives at block **850** it will have taken all required numerical data, performed all required parameter table modifications, or performed all required vector processing operations. As will now be explained, the remainder of the flow chart of FIG. **8** is directed to storing a semi-permanent copy of the parameter table in EROM **46**.

If, on arriving at block **850**, the processor finds that the "flash" flag has not been set, it knows that the contents of the parameter table have not been changed and, consequently, that no updated copy thereof needs to be stored in EROM **46**. Under this condition, the processor is directed to simply return to the main program of FIG. **6**A. If, on arriving at block **850**, the processor finds that the "flash" flag has been set, however, it knows that the contents of the parameter table have been changed and, consequently, that an updated copy thereof needs to be stored in EROM **46**. Under this condition, the processor is directed to blocks **855**, **860** and **865**, which defines the steps necessary to store this updated copy.

In accordance with block **855**, the processor is instructed to copy from EROM **46** to RAM **45**, the program instructions (flash routine) necessary to copy the parameter table from RAM to EROM. The copying of the flash routine to RAM is necessary because the EROM cannot be written to when the apparatus is reading or operating from the EROM. Once the flash routine has been copied to RAM **45**, the processor is directed to jump to RAM to begin executing that routine. As it does so it is directed, via block **860**, to erase the old (unchanged) parameter table from EROM **46**. Per block **865**, it then copies new (changed) parameter table from RAM **45** to EROM **46**. Once this has been done, the processor is directed back to the main program of FIG. **6**A to begin operating in accordance with the operating mode specified by its new parameter table. Thus, the performance of the steps called for by blocks **855**–**865**, when called for by block **850**, has the effect of partially reprogramming the reader so that it operates in the manner indicated by the last menuing symbols selected by the user.

Referring to FIGS. **8**A–**8**D, there are shown examples of menu symbol selection charts of the type that may be used. Referring first to FIG. **8**A, there are shown two parts of an option selection or menu chart that is used to enable and disable two exemplary 1D bar code symbologies, namely: Code 128 and UPC A. If a user wants to enable the decoding of Code 128 symbols, he need only image menu symbol **802** which, in the present example, is a 2D bar code symbol expressed in the Aztec bar code symbology. Conversely, if a user wants to disable the decoding of Code 128 symbols, he need only image menu symbol **804**. Similarly, imaging symbols **806** or **808** enables or disables the decoding of UPC A symbols. Advantageously, the change called for by the user is accomplished as the result of a single imaging step, rather than as a result of multiple imaging steps.

Referring to FIG. **8**B, there are shown two parts of an option selection chart that is used to select the desired one of the baud rates that may be used by the reader's I/O devices. A user chooses the desired one of the exemplary 1200, 9600, 19200 and 38400 baud rates by simply imaging the corresponding ones of menu symbols **812**–**818**. Again, the change is accomplished as the result of a single imaging step.

The fact that the above-discussed examples of menu selections make use of menu symbols that use the Aztec 2D symbology is not essential to the practice. Other 2D or 1D menu symbol symbologies could also have been used, if desired, as will be seen from the following discussion of FIGS. **8**C and **8**D. What is important is that the symbology used for the menu symbols be the one that is correct for the model indicated by the product ID field of the menu word. In the case of FIGS. **8**A and **8**B, the illustrated menu symbol symbology is that which is used by the IMAGETEAM™ Model 4400 reader manufactured by Welch Allyn, Inc.

Referring to FIG. **8**C, there are shown exemplary parts of the option selection or menu chart that can be used with Welch Allyn SCANTEAM® readers. In FIG. **8**C, symbol **822** is an example of a menu symbol that, if imaged, causes all Code 11 and Code 128 settings to assume their default values. Symbols **824** to **836** are examples of menu symbols that allow Code 11 options to be enabled and disabled on an individual basis. Similarly, symbols **848** to **856** are examples of menu symbols that allow Code 128 options to be enabled and disabled on an individual basis.

Referring to FIG. **8**D, there are shown further exemplary parts of the option selection or menu chart that may also be used with Welch Allyn SCANTEAM® readers. In FIG. **8**D symbol **858** is an example of a menu symbol that, if imaged, causes the settings for one of the RS-232 ports of the reader to assume their default values. Symbols **862** and **864** are examples of menu symbols that enable and disable a CTS check selection feature. Finally, symbols **866** through **884** are examples of menu symbols that allow any of a number of different baud rate selections to be made. Once again, the present reader allows all of these menu selections to be made by means of a single step selection process.

Because fuller information concerning the menu options contemplated, and their uses is contained in the User's Manual for the above-identified readers, these menu options will not be discussed further herein.

Reprogramming

In accordance with another feature of the apparatus and method, the reader may be reprogrammed to operate in accordance with an entirely new application program. This means that the reader may not only be provided with a new or updated decoding program, or a new parameter table, it may also be provided with one or both of a new menuing routine and a new main program. As a result, a reader may be effectively reconfigured as a new reader, with new capabilities and features, as often as necessary to keep it up to date with the latest developments in optical reader technology. Advantageously, this reprogramming may be accomplished either locally as, for example, by a local host processor equipped with a diskette or CD-ROM drive, or remotely by a distant processor that is coupled to the reader via a suitable telephone or other transmission line or via a computer network or bulletin board.

The reprogramming feature will now be described with reference to the system block diagram of FIG. **9** and the reprogramming flow chart of FIG. **10**A. Referring first to FIG. **9** there is shown a reader **10**, of the type shown in FIG. **4** or **5**, which is coupled to a local host processor **900** by means of multi-conductor flexible cable **54**. The reader may also comprise a cordless battery powered reader **10'** which is coupled to a host processor **900** via a suitable RF link including antennae **905** and **910** and an RF interface module **915**. Host processor **900** is preferably equipped with a display **930** by which the results of the previously described vector processing operations may be displayed, and with a printer **940** by which the previously described menuing bar code symbol may be printed. As used herein, the term "local host processor" will be understood to include both stand alone host processors and host processors which comprise only one part of a local computer system.

If the new reader program is available locally as, for example, on a diskette or CD-ROM, it may be loaded into reader **10** or **10'** using a suitable drive unit **920**, under the control of a keyboard **925** and the reprogramming routine shown in FIGS. **10**A and **10**B. In addition to drive unit **920**, processor is typically in communication with a read only program storage device such as a ROM **921** and a read/write storage device such as a RAM **922**. If the new reader program is available at a remotely located processor **950**, it may be loaded into reader **10** or **10'** through a suitable transmission link **955**, such an electrical conductor link, a fiber optic link, or a wireless transmission link through a suitable communication interface **960**, such a modem. As used herein, the term "transmission link" will be understood to refer broadly to any type of transmission facility, including an RS-232 capable telephone line, as called for by communication option A**1** of FIG. **7**B, an RF link, as called for by communication option A**3** of FIG. **7**B, or a computer network, e.g., ETHERNET, as called for by communication option A**4** of FIG. **7**B, although other types of transmission links or networks may also be used. For example, transmission link **955** could be provided by a coaxial cable or any other non-RF electromagnetic energy communication link including a light energy infrared or microwave communication link. Link **955** could also be an acoustic communications link. Additional communication options include a baud rate option A**2** which allows different baud rates to be selected.

The manner in which the reader may be made to perform any of a variety of different externally specified functions, including reprogramming itself, will now be described with reference to the flow charts of FIGS. **10**A and **10**B. As will be explained more fully presently, the flow chart of FIG. **10**A is a flow chart by which a program originating outside of the reader may be loaded into the reader for execution thereby. One example of such an externally originated program is the reprogramming program shown in FIG. **10**B. Other examples of such externally originated programs may include diagnostic or test programs, among others.

Turning first to FIG. **10**A, this flow chart is entered when the reader receives an externally generated command, such as the six character sequence BBOOTT, which it is programmed to recognize and respond to. This command may be initiated either by a local or a remotely located processor and transmitted to the reader via any of the I/O devices shown in FIG. **1**. It may, for example, be initiated by the local host processor via keyboard **945** or by remote processor **950**. This command may be given effect as an interrupt request and recognized as such by decision block **1005** of FIG. **10**A. it will be understood that while interrupt block **1005** is shown in FIG. **10**A, it may in fact be located at any point within the main program of the reader.

Once the BBOOTT command has been received and acted on, the processor enters a loading loop including blocks **1007** through **1020**. This loading loop causes the processor to load a program into RAM, one line at a time, in conformity with any suitable communication protocol, until the last line of code is detected via block **1020**. When the latter has occurred, the processor is directed to block **1025**, which causes it to jump to the newly received program and to begin executing the same before returning to the main program.

Referring to FIG. **10**B, there is shown an exemplary flow chart for a reprogramming routine suitable for use in reprogramming the reader to operate with new or different decoding programs, and or new or different menuing programs, among others. This program is an example of a program which may be executed as a result of the execution of the loading loop **1007**-**1020** of FIG. **10**A, and which begins to be executed as the processor enters block **1025** of FIG. **10**A.

On executing the reprogramming flow chart of FIG. **10**B, the device loads the program that is intended to replace all or part of the program currently stored in EROM. This process begins as the processor encounters block **1035**,

which directs it to wait until a line of externally generated code is received. As each line of code is received, it is first checked for correctness (e.g. checksum), as called for by block **1040** and, if an error is found, sends a negative acknowledgment signal to the sending processor per block **1045**. Each time that a correct line of code is received, the flow loops back for additional lines until the last line of the current file has been correctly read, as called for by block **1050**. Since the last line of the file does not contain program data, and cannot occur until all blocks of program data have been processed, block **1050** will direct the processor to block **1060**, unless and until all blocks of program data have been received and stored in EROM **46**, and then cause it to return to the main program of FIG. **6**A via exit block **1055**.

If the processor has not exited the reprogramming routine of FIG. **10**B per blocks **1050** and **1055**, block **1060** will cause it to determine if the last received line indicated that a new block has begun. If it has, the processor is directed to block **1065**, which causes it to erase that new block of EROM before continuing to block **1070** and storing that last received line therein. If it has not, block **1070** will cause the processor to store the last received line to the last erased block of EROM. If this line has been successfully stored, as determined by block **1075**, the processor will acknowledge that fact per block **1077** and loop back for another line.

If, however, any line of data has not been successfully stored, block **1075** will direct the processor to a block **1080** which causes it to output an error message and exit the program. If the latter occurs, the reprogramming routine as a whole must be repeated. If the latter does not occur, the above-described process will continue line-after-line, block-after-block, until the entire file has been successfully transferred.

In view of the foregoing, it will be seen that the effect of the reprogramming routine of FIG. **10**B is to attempt to reprogram part or all of EROM **46** as requested, or to continuing the attempt to do so until it either succeeds or fails. To the extent that the reader is reprogrammed, it will effectively become a new or updated reader. This is not only because this reprogramming can not only modify the parameter table, it can also modify the decoding or other programs referenced by the parameter table and the menuing program itself. Thus, the reprogramming feature can not only change the manner in which the reader operates, it can also change the manner in which the operation of the reader can be modified in the future.

With the use of the above-described reprogramming feature, the reader of the invention may be kept current with the latest available programs that are suitable for use therewith. A user at local processor **900** may, for example, communicate with remote processor **950**, via keyboard **925**, and determine if new programmable features are available. If they are, he may obtain them from the remote process and download them locally, or request that the remote processor download them directly to the reader. Alternatively, the remote processor may initiate the reprogramming of the reader independently as, for example, pursuant to a service contract or updating service. It will be understood that all such embodiments are within the contemplation.

Local Host and Reader System Operations

As has been described hereinabove, reprogramming of a reader may be accomplished with use of a local host processor. This section describes additional features of a system comprising a local host processor **900** and a reader **10** and more particularly describes features and additional system operations that are realized by various interaction between host processor **900** and reader **10**, and in certain applications by a host processor **900** that is not in communication with a reader **10**.

A flow diagram illustrating the primary program for operating a local host processor for use in controlling a reader is shown in FIG. **11**A. By executing block **1102** host processor causes to be displayed on a display monitor **930** a subprogram option screen. The subprogram option screen displays various subprogram options for a user to select. Selection of one subprogram option causes a series of instructions pertaining to that particular option to be executed by local host processor **900**. These subprograms of a host primary program controlling local host processor may include, for example, a subprogram for reprogramming a reader; a subprogram for uploading parameter information from a reader to host, or information pertaining to a main program presently operating a reader; a subprogram for instructing a reader to perform self-diagnostic testing; a subprogram for determining the reader's main program revision level; a subprogram for outputting parameter table information, possibly to auxiliary readers; a subprogram for editing parameters of a parameter table; a subprogram for simulating the result of applying editing commands to a decoded message; and a subprogram for displaying barcode symbols for scanning by a reader.

A flow diagram illustrating a subprogram for reprogramming of a reader **10** by control of a local host processor is shown in FIG. **11**B. Whereas FIGS. **10**A and **10**B illustrate instructions executed by processor **40** of reader **10** for providing reprogramming of a reader, FIG. **11**B illustrates instructions executed by local host processor for providing reprogramming of a reader.

At block **1110** host processor **900** displays a main reprogramming screen on display monitor **930**. The main reprogramming screen prompts a user to designate a source for an operating program. The source designated is typically a bulk storage device such as a hard or floppy disk drive but also may be, for example, a RAM or ROM storage device. When the source is selected, host processor **900** displays on display monitor **930** indicators of the operating programs, or files, that are available in the storage device source selected (block **1114**) and a user selects one of the operating programs. Some available operating programs comprise entire main programs and entire parameter tables for loading into reader, whereas other available operating programs include only parameter tables which may be customized parameter tables created by a user during execution of a parameter table editing subprogram.

When a user selects a source for an operating program, and selects a desired operating program, downloading of the operating program proceeds. At block **1116** host processor determines whether a reader is connected to the host processor communications link, normally by serially transmitting a device detection command to a reader, which has been previously programmed to transmit an acknowledge response message on the reception of a detection command.

If a reader is connected to host processor **900** then host processor at block **1118** sends an identification command to reader **10** which is previously programmed to transmit an identification response on the reception of an identification command. After receiving the identification response and comparing the response to the selected operating program at block **1120** processor at block **1122** determines whether the reader is of a type which is compatible with the selected operating program. An operating program is compatible with a reader in communication with host processor if the operating program is specifically adapted for that reader's unique hardware configuration. Bar code readers of various

types have different hardware components including different memory devices, image sensors, input/output devices, and other components. The selected operating program must be in form enabling it to communicate with the particular hardware components of the presently connected reader.

If the selected operating program is compatible with the present reader, the host processor at block **1126** determines if the operating program is a parameter-only type operating program or an operating program that comprises a main program and a parameter table. This determination can be made, for example, by reading the contents of a DOC type file which is made to be read by processor **900** when an operating program is read, and which is made to include an identifier as to whether the operating program is of a type which includes a main program and parameter table; by reading the contents of a predetermined address of the operating program which is made to include an identifier as to the type of operating program; or by reading predetermined addresses of an operating program designated for storing a main program and basing the determination on whether instructions are present in the designate addresses.

A memory map for a typical operating program is shown in FIG. **11**C. When an operating program is stored in a memory device, which may be, for example EROM **46** of reader **10**, or a disk drive **920** or other storage device associated with host processor **900** a plurality of first predetermined address locations e.g. 000 to 5000 of the storage device are designated for storing parameters of the main program, while a plurality of second predetermined address locations e.g. 8000 to 9000 are designated for storing instructions of a parameter table. The beginning and end addresses of the parameter table may change from operating program to operating program. However, the parameters of each parameter table are in identical locations with respect to the beginning address.

When host processor **900** determines at step **1126** that the selected operating program includes a main program then program control proceeds to step **1130** wherein processor transmits the contents of the selected operating program into EROM **46** of reader **10**. If host processor **900** determines at block **1126** that the selected operating program is a parameter only type operating program then host processor **900** first queries EROM **46** to determine the begin and end address locations of the parameter table of the operating program currently stored in EROM. To this end host processor **900** at block **1130** polls the contents of a vector pointer table **1134** in predetermined address locations of EROM. Described previously herein vector pointer table **1134** comprises the beginning and end addresses of the parameter table. After vector pointer table is polled, host processor **900** stores the address location of the present parameter table, modifies the parameter table address of the selected parameter-only operating table in accordance with the parameter table addresses of the existing parameter table (block **1136**) and writes the contents of the parameter table address locations of the modified parameter-only type operating program into EROM **46** (block **1140**).

If processor **900** determines at block **1126** that the selected operating program is of the type having a main program and a parameter table, then processor **900** at block **1144** prompts the user whether the user would like to save the contents of a parameter table of the operating program currently stored in EROM **46** of reader **10**; that is, utilize the parameters of the current operating program in the operation of a reader that is programmed to have a new main program. If the user responds affirmatively, then processor **900** reads the contents of the existing parameter table (block **1150**) after first polling the vector pointer table and then writes, at block **1152**, the contents of the existing parameter table in a predetermined holding address location of a storage device associated with processor **900** or reader **10**.

The selected operating table is then written into EROM **46** at block **1140**, line by line, until loading is complete. If the user had requested at block **1144** to save the contents of the original parameter table (a determination made at block **1153**), then processor **900** writes the contents of the parameter table stored in a holding address location to the appropriate parameter address locations of EROM at block **1154**, after determining the address locations of the parameter table at block **1156**. Referring again to the primary host processor program shown in FIG. **11**A, another subprogram which can be selected from subprogram option screen displayed at block **1102** is a subprogram for editing a parameter table via host processor control. An important feature available in this subprogram is that the subprogram allows a user to edit a parameter table read from a memory location of processor **900** or reader **10** without there being a reader currently in communication with processor **900**, thus improving the convenience of operation.

As discussed previously with reference to FIG. **7**B, a parameter table is used to specify operating options that are subject to the control of the user. During execution of instructions of a reader's main program stored in a first predetermined memory locations of a storage device, parameters of a parameter table, which is stored in a second predetermined set of memory address locations of a storage device, are called up with use of lookup type instruction as exemplified by representative lookup instruction (in pseudocode) **1160** shown in FIG. **11**C. Parameters of a parameter table may be, for example, communications option parameters (subheading A), code option parameters (subheading B), scanning-decoding option parameters (subheading C), operating option parameters (subheading D), transmit option parameters (subheading E), data formatter command parameters (subheading F), prefix/suffix parameters (subheading G), or other types of parameters.

A flow diagram for a parameter table editing subprogram is shown with reference to FIG. **11**D. At block **1162** processor **900** determines if a reader is in communication with processor **900** in the fashion described previously with reference to block **1116** of FIG. **11**B. If a reader is present, processor **900** at block **1166** reads the parameter table presently stored in EROM **46** (after determining the table's location), along with a list of analog waveform outputs from another predetermined memory location from EROM **46**. A list of possible types of analog waveform outputs a reader may be configured to generate allowing the reader to transmit data to various types of terminals is stored in a predetermined waveform list memory location. The waveform list memory location may be determined by querying vector pointer table **1134**. A specific one type of waveform output from the list of available outputs is selected by control of a parameter of parameter table, typically stored in an address location corresponding to Communications Options (Heading A) type parameters described previously with reference to FIG. **7**B. Processor **900** at block **1116** stores the parameter table and the list of analog waveform outputs in a temporary storage device associated with processor **900** such as a RAM.

In the embodiment shown, the parameter table editing subprogram is configured by default to edit the existing parameter table stored in EROM of the connected reader if a reader is present. It will be recognized, however, that the editing subprogram can also be configured to query the user

as to whether the user wishes to edit the parameter table currently stored in reader EROM **46**, or another candidate parameter table typically stored in a bulk storage device associated with processor **900**.

If a reader is not in communication with processor **900**, continuing with reference to the flow diagram shown, then processor at block **1168** prompts the user to select a reader for which the user wishes to edit a parameter table and once a type of reader is selected, a default parameter table associated with that reader type is written in to a temporary storage device of processor **900** typically provided by a RAM device.

At the termination of block **1168** or block **1166** if a reader is connected, a parameter configuration screen is displayed to a user, at block **1169**, an exemplary embodiment of which is shown in FIG. **11**E. Typically, a user will edit certain parameters from the parameter table which the user wishes to change, and then, when editing is complete, a user will select an available output option from the parameter configuration screen. The output options available to a user may include writing an edited parameter table to a connected reader; writing an edited parameter table to a bulk storage device; displaying an edited parameter table; or printing an edited parameter table.

Until an output option is selected, the user typically edits various parameters the user wishes to change as shown in blocks **1170** and **1172**. Selection of one parameter type option, e.g. code or symbology option parameter **1174** causes a secondary editing screen to appear allowing editing of parameters of the selected parameter type. When editing pertaining to one or several parameter types is complete then program reverts back to parameter configuration screen at block **1169**, allowing user to select an output option.

If a user selects the write output option (block **1176**), the edited parameter table is written to, or downloaded to reader EROM in the fashion described previously with reference to block **1140** of FIG. **11**B. If a user selects the store-to-disc option (block **1178**) then the edited parameter table is written to an address location of a bulk storage device such as a hard drive or floppy disc. If a user selects the display option (block **1180**) then processor **900** causes the complete or partial contents of the edited parameter table to be printed on display screen associated with host processor **900**. If a user selects the print option (block **1182**) then processor **900** causes the complete or partial contents of the edited parameter table to be printed by a printer device **940** in communication with processor **900**.

Another output option available to a user is to compare two or more parameter tables. If this option is selected (block **1184**) then the user is requested at block **1186** to select parameter tables from memory locations (which may be memory location associated with processor **900** or with reader **10**). When parameter tables have been selected, processor **900** at block **1186** compares the selected parameter tables. In general, the comparison is carried out by a compare function applied after an offset between the files is accounted for. Processor **900** then outputs the results of the comparison at block **1188**, typically by displaying the comparison results on screen **930**, or printing the comparison results using printer **940**.

One specialized output option allows the user to create programming menu symbols whose general features have described with reference to FIG. **7**A–**7**C, and **8**. The menu symbols created by the output option can be used to reprogram readers reading the created symbols in accordance with the changes made to a parameter table made during execution of the parameter table subprogram. Described as a routine executed during a parameter table editing subprogram, the menu symbol output option can be conveniently implemented as a separate subprogram.

When a menu symbol output option is selected at block **1189**, processor **900** determines at block **1202**, by reading a reader identifier, whether the reader designated for receipt of the edited parameter table includes a one dimensional (1D) or two-dimensional (2D) image sensor.

If the reader includes a one dimensional image sensor, then processor **900** creates a series of linear bar codes which may be used for reprogramming several readers. Specifically, if the designated reader includes a one dimensional image sensor then processor **900** at block **1204** creates a first linear menu symbol adapted to generate an instruction causing the reader reading the symbol to change parameter table values of the reader's EROM to default values. Then, at block **1206** processor **900** creates a distinct linear programming menu symbol for each parameter of the parameter table that is changed during the editing process from a default value. An important feature is described with reference to block **1208**. When the series of menu symbols is created, the created symbols may be printed on paper by printer **940** according to a conventional protocol, or else displayed on display device **930**, typically a CRT monitor. The term created symbols herein refers to binary encoded data stored in a memory space which result in an actual symbol being output when the data is written to a display device or printer. An unlimited number of bar code readers may be reprogrammed by reading the menu symbols that are displayed on the display device **930**. Displaying the created menu symbols on a display device allows rapid output of created symbols and eliminates the need to supply a paper substrate each time a menu symbol is output.

If the reader designated for reprogramming includes a 2D image sensor, then processor **900** at block **1210** need only create one 2D menu symbol in order to cause reprogramming of the designated reader in accordance with the changes made to a parameter table even in the case where multiple changes to the parameter table are made. This is so because an increased number of instructions may be encoded in a symbol of a 2D symbology type.

Another subprogram which may be selected from a subprogram option screen displayed at block **1102** is a subprogram for simulating the result of applying editing commands to a decoded message. As discussed previously, editing commands may be applied to decoded messages by entry of the commands to a parameter table in parameter table addresses corresponding to heading H of FIG. **7**B. Without an editing command simulation subprogram, it would be necessary to decode a symbol with use of reader **10** in order to observe the result of applying the editing commands. The efficiency and convenience advantages of the editing command simulation subprogram therefore should be clear to those skilled in the art.

An exemplary flow diagram for an editing command simulation subprogram is shown in FIG. **11**E. At block **1214** processor **900** displays a message editing simulation screen or screens which allows a user to enter an unedited test message and symbology type (block **1216**) and enter the type of editing command desired to be applied to the message (block **1218**). Three basic types of editing commands are search and replace editing commands, insert character editing commands, and delete character editing commands. Additional, more complex editing commands may also be applied.

When the commands are entered, processor **900** applies the commands entered at block **1218** to the unedited test

message at blocks **1220**, **1222**, and **1224** if all are applicable. When editing is complete processor **900** outputs the result of applying the editing commands, at block **1226**, typically by displaying the edited message on display screen **930**.

At block **1228** processor queries the user as to whether the user wishes to save the editing commands which resulted in the edited message being displayed or otherwise output at block **1226**. If the user elects to save the editing commands, then processor **900** at block **1230** writes the commands to a predetermined command save memory location associated with processor **900**. When the parameter table editing subprogram described with reference to FIG. **11**D is later executed the commands saved in block **1230** of the message editing command subprogram may be read from the command save memory location during execution of block **1192** of the parameter table editing subprogram.

In addition to being adapted to download new or modified operating programs to reader **10** remotely, processor **900** can also be adapted to remotely transmit component control instructions to reader **10** which are executed by reader processor **40** substantially on receipt by reader **10** to control one or more components of reader **10** in a manner that can be perceived by a reader operator. For example, processor **900** and reader **10** can be arranged so that processor **900**, on receipt of a command from a user, transmits a component control instruction to reader **10** which is executed by reader processor **40** to have the same effect as trigger **52** being manually pulled, or alternatively, being released. Instructions transmitted by processor **900** having the same effect as manually pulling and manually releasing trigger may be termed, respectively, "remote trigger activation" and "remote trigger release" instructions. Processor **900** and reader **10** can also be complementarily arranged so that, on receipt of a user activated command to remotely control reader **10**, processor **900** transmits to reader **10** an instruction which is executed by reader **10** substantially on receipt of the instruction to turn on LED's **22** or to "flash" LED's according to a predetermined pattern, or to activate an acoustic output device such as speaker **38** to issue a "beep" or a series of beeps. Component control instructions for on-receipt execution which operate to control LED's **22** or speaker **38** are useful, for example, to signal an alarm condition, to indicate that a task is completed, or to attract the attention of a reader operator for any purpose.

Processor **900** and reader **10** can also be complementarily arranged so that, on receipt of a user activated command, processor **900** transmits to reader **10** a component control instruction which is executed by reader **10** substantially on receipt thereof to transmit data which is stored in memory **45** or in another memory device associated with reader **10** such as a long-term nonvolatile memory device. For example, a component control instruction received from processor **900** may be executed by reader **10** to upload from reader **10** to processor **900** image data that is stored in a specific memory location of reader memory **45** such as a reader memory location that stores the most recently captured image data captured by reader. Processor **900** may subsequently display such uploaded image data on display **930**. Other component control instructions which may be transmitted from processor **900** to reader **10** for substantially on-receipt execution by reader processor **40** are instructions which, for example, cause predetermined indicia to be displayed by reader display **56**, or which cause processor **40** to capture, by appropriate control over image sensor **32**, a single frame of image data corresponding to the scene presently in the field of view of reader **10** in memory **45** or in another memory device.

It will be understood that certain component control instructions require that reader processor **40** execute a series of instruction steps, or repetitive instruction steps to cooperatively control more than one reader component. For example, a component control instruction commanding an optical reader to capture an image normally requires that processor **40** execute a series of instruction steps involving control of such components as LED's **22**, components of the imaging assembly, and memory **45**.

A modified reader operating program that adapts a reader to receive component control instructions from a remote local host processor for substantially on-receipt execution by reader **10** is shown in FIG. **6**B. Reader **10** is readily enabled to receive and execute remote component control instructions by modification of the program loop indicated by block **605** of FIG. **6**A wherein reader **10** waits in a low power state until a trigger is pulled. As shown by the flow diagram of FIG. **6**B, block **605** may be modified to the form illustrated by block **605'** so that reader executes block **610** and the ensuing blocks shown and described in connection with FIG. **6**A in response either to a trigger being manually pulled or to the receipt of a remote trigger activation instruction from processor **900**. Block **635** of the flow diagram of FIG. **6**A may also be modified so that the reader is responsive either to a manual trigger release or to receipt of a remote trigger receive instruction. Reader **10** may also be made to exit the loop indicated by block **605'** on the condition that another component control instruction for on-receipt execution by reader **10** is received. As is indicated by block **602** and block **603**, reader **10** may be adapted to exit the loop indicated by block **605'** and to appropriately control the component associated with the received instruction on the condition that a remote component control instruction is received from processor **900**.

Scanning-Decoding/Autodiscrimination

The scanning-decoding and autodiscrimination features, and their relationships to the above-described menuing and reprogramming features, will now be described with reference to FIGS. **6** and **12**–**18**. More particularly, the combined operation of these features will be discussed in connection with FIG. **6**A. The SOD, SS and DOD scanning-decoding modes will be discussed in connection with FIGS. **13** and **14**, and the OS, RUD and RUS scanning-decoding modes will be discussed in connection with FIG. **15**. Finally, the 1D and 2D portions of the autodiscrimination feature will be discussed in connection with FIGS. **16**–**18**, respectively.

Turning first to the main program of FIG. **6**A, the scanning and decoding operations are shown as blocks **625**–**647**. In those embodiments or modes in which the multiple symbols code option is not enabled (see option B**5** of FIG. **7**B), the processor assumes, that only one symbol is to be decoded. Under this condition, if decoding is successful, the processor processes the decoded symbol as a menu symbol in accordance with previously described menu routine **660**, or as output data in accordance with block **646**, and then is stopped by one of blocks **647**, **635** or **642**. If decoding is not successful, the processor is directed back (unless stopped by blocks **635** or **642**) to capture and attempt to decode another image. In this case, the "no" output of multiple symbols block **643** is selected, allowing additional images to be captured as necessary.

In those embodiments or modes in which the multiple symbols option is enabled, the processor assumes that more than one symbol is present in the image data. Under this condition, if decoding is successful, the processor continues to loop back to block **627** to make additional decoding attempts, unless stopped by one of blocks **635** or **642**. In this case, however, the "yes" output of block **643** is selected, preventing additional images from being captured.

When the processor begins executing its scanning-decoding program, it first determines from the parameter table which scanning-decoding option or combination of options is to be used. It will then be directed to an autodiscrimination routine that is configured to execute that routine in accordance with the selected scanning-decoding option or options.

At start up, the parameter table maybe set up so that operation in the One Shot scanning-decoding mode is established as a default condition. Alternatively, the parameter table may be set up so that the RUD or RUS scanning-decoding mode is established as a default condition. Since the One Shot mode is inherently a non-tracking mode, its selection as a default mode implies that none of the tracking modes is selected. Since the RUD and RUS modes can be used either with or without one of the three tracking modes, its selection as a default parameter may or may not be associated with one of the three tracking modes, depending upon how the reader is programmed at the time of manufacture.

(a) Tracking Options

The differences between the three tracking modes of the invention are best understood with reference to FIGS. **12**–**14**. The latter figures (with changes in figure and indicia number) are incorporated from prior copending U.S. patent application No. 08/914,883, now U.S. Pat. No. 5,942,741, together with their associated descriptions as follows:

Scanning of indicia can take place under either of two generalized conditions, depending upon the decoding load presented by the indicia. Under light decoding loads, shown in FIG. **12**A for a prior art reader, the amount of data to be decoded is relatively small, allowing scan data from a complete scan to be decoded in a time which is less than the duration of a scan. Under this condition, the result of each scan is decoded before the completion of the following scan, and no problems arise as a result of any mismatch between the scan time and the decode time of the reader. The prior art and the instant reader perform equally well under such light decoding loads as will be seen later from FIG. **13**.

Under heavy decoding loads, however, prior art methods do not allow sufficient time for decoding. Thus, as shown in FIG. **12**B, when a first scan, Scan **1** is completed, a second scan, Scan **2** is initiated immediately. Scan **2** is then followed by Scan **3** while the decoding of Scan **1** is still in progress. As this situation continues, the decoding process will be seen to fall further and further behind the scanning process until, at some point, the data memory becomes filled. When this occurs new scan data will overwrite old scan data which was not processed, thereby causing a loss of large blocks of scan data.

In the embodiment disclosed in prior copending application No. 08/205,539, now issued as U.S. Pat. No. 5,463,214, this problem is solved by modifying the reader in a way that allows the scanning process to be suspended and restarted as required to prevent the decoding process from falling so far behind the scanning process that data overflows the memory and is lost. This embodiment is referred to herein as the "Scan on Demand" or SOD tracking mode. This solution to the problem may be understood with reference to FIGS. **13**A and **13**B. Referring to FIG. **13**A, there is shown the operation of the subject embodiment under light decoding loads. It will be noted that, under this condition, the relationship between scanning and decoding is the same as that shown in FIG. **12**A.

FIG. **13**B shows the relationship which exists between the scanning and decoding processes when the Scan On Demand mode is used under heavy decoding loads. As shown in FIG. **13**B, the suspension of the scanning process continues until the results of the prior scan have been decoded. This prevents the decoding process from falling more than a small amount of time behind the scanning process. As a result, there cannot arise a situation, such as that which can arise with the prior art, in which there is a massive loss of scan data. Because this process is described in detail in U.S. Pat. No. 5,463,214, it will not be described in detail herein.

Referring to FIG. **13**C there is shown the tracking relationship which exists between the scanning and decoding operations when these operations are controlled in accordance with a tracking mode referred to as the "Skip Scan" or SS tracking mode. With this mode, under heavy decoding loads, decoding proceeds without interruption so long as the scanning function is called for. As shown in FIG. **13**C, each decoding operation begins immediately after the preceding decoding operation ends, and proceeds on the basis of the scan data from the then most current complete block of scan data.

More particularly, FIG. **13**C illustrates one possible scenario in which decoding of Scan **1** data is immediately followed by the decoding of Scan **2** data. This occurs because Scan **3** data is incomplete at the time that the second decoding operation begins. The decoding of Scan **2** data, however, is immediately followed by the decoding of Scan **5** data. This occurs because Scan **5** data represents the then most current complete block of scan data. While the results of scans **3** and **4** are therefore unused and skipped over, the data lost by their non-use is provided by more current scan data or, if decoding is unsuccessful, by the results of a later scan. Any occasional decoding failure that results from the skipping of relatively old blocks of scan data is in any case more than offset by the avoidance of the large scale data losses discussed in connection with FIG. **12**B.

Referring to FIG. **13**D there is shown the tracking relationship which preferably exists between the scanning and decoding operations when these operations are performed in a reader which includes two and only two scan data memory spaces A and B. With this reader, the preferred tracking mode is the "Decode on Demand" or DOD tracking mode. With this mode decoding does not proceed without interruption. As shown in FIG. **13**D, each decoding operation begins at the beginning of a block of scan data. In the event that the end of a decoding operation does not coincide with the beginning of such a block, i.e., occurs while a scanning operation is still in progress, the beginning of the next decoding operation will be delayed until the scanning operation that is then in progress is completed, and then proceeds with reference to the block of scan data which is produced by that scanning operation.

More particularly, FIG. **13**D shows that the decoding of Scan **1** data is completed while Scan **3** is still in progress, overwriting data for Scan **2**. Under this condition, decoding is discontinued for a time period T_{s1} that is equal to the time necessary for Scan **3** to be completed. At the end of time period T_{s1}, decoding resumes with the then most current block of scan data, namely: the scan data produced during Scan **3**. Thus, like the mode which is illustrated FIG. **13**C, the mode which is illustrated in FIG. **13**D begins its decoding operation with the then most current complete block of scan data.

Referring to FIG. **13**E, there is shown the tracking relationship which exists between the scanning and decoding operations when these operations are performed in a reader which includes three scan data memory spaces A, B and C. With this embodiment decoding proceeds without interrup-

tion so long as the scanning function is called for. As shown in FIG. **13**E, each decoding operation begins immediately after the preceding decoding operation ends, and proceeds on the basis of scan data from the memory which contains the then most current complete block of scan data.

More particularly, FIG. **13**E shows that the decoding of Scan **1** is completed while Scan **3** is still being acquired. Under this condition, with three memory spaces available, decoding is immediately undertaken on the most recent complete Scan (Scan **2**) which is contained in memory space B. Upon the completion of the decoding of Scan **2**, decoding is commenced on Scan **4** which is contained in memory space A. Thus, the utilization of three memory spaces allows the decoding portion to be occupied one hundred percent of the time.

The mode illustrated in FIG. **13**C is best suited for use with readers having memories and addressing procedures which can accommodate large numbers of relatively short blocks of scan data having sizes that are not known in advance. Applications of this type typically include readers, such as that shown in FIG. **3**, which use 1D image sensors.

The modes illustrated in FIGS. **13**D and **13**E, on the other hand, are best suited for use with readers having memories and addressing procedures which can accommodate small numbers of relatively long blocks of scan data of fixed length. Applications of these types typically include readers, such as that shown in FIG. **2**, which use 2D image sensors. With the embodiment illustrated in FIG. **13**D, only two scan data memory spaces are used and decoding is discontinuous. With the embodiment illustrated in FIG. **13**E three scan data memory spaces are used and decoding is continuous. More than three scan data memory spaces can also be used if additional decoding resources are made available. The one of these different embodiments which is used in a particular application is a design choice which is based on economic considerations.

The fact that some embodiments use 1D image sensors while others use 2D image sensors should not be taken to mean that embodiments which use 1D image sensors can only read 1D symbols or that embodiments which use 2D image sensors can only read 2D symbols. This is because techniques exist for using either type of image sensor to read both 1D and 2D symbols. It will therefore be understood that the present reader is not restricted to use with any one type of image sensor or to any one type of bar code or other optically encoded symbol.

Referring to FIG. **14**A, there is shown a memory space **M1** suitable for use in storing blocks of scan data of the type produced by a reader with a 1D image sensor, together with a pointer or tracking memory **M2** suitable for use in storing address or pointer information that makes it possible for the reader to identify the beginning and end point of a block of interest. As shown in FIG. **14**A, the block of scan data produced during a first scan of the target is stored in memory **M1** beginning at address SS**1** (Scan Start for Scan **1**) and ending at address SE**1** (Scan End for Scan **1**). Similarly, the block of scan data resulting from a second scan of the target is stored between addresses SS**2** and SE**2**, and so on. Because scanning takes place continuously, the end of one scan block (e.g. SE**1**) coincides with the beginning of the next scan block (e.g., SS**2**). The sizes (in memory space) of these blocks will ordinarily vary from block to block, depending on the number of data transitions in each 1D scan of the target. The boundaries between blocks will, however, be fixed by the occurrence times of the Scan Interrupt signals which are generated by the image sensor or its clock generating circuitry.

Locations SS and SE of memory M**2** are updated in the course of a series of scans so that they always identify or otherwise point to the address of the beginning and ending of the most recently produced complete block of scan data. As a result, when the decoding circuitry is ready to decode the most recently produced complete block of scan data, it need only refer to locations SS and SE to obtain information as to where to begin and end decoding. Before decoding begins, the contents of locations SS and SE are written into locations DS (Decode Start) and DE (Decode End) so that locations SS and SE can continue to be updated while decoding proceeds on the basis of the contents of locations DS and DE. In the preferred embodiment, the decoding circuitry is programmed to mark these beginning addresses as "invalid" (for example, by changing its sign) after it is acquired. Since the decoding processor is programmed to decode only "valid" data, this assures that it can decode a single block of scan data only once.

Referring to FIG. **14**B there are shown a plurality of memory spaces MA, MB . . . MN suitable for use in storing blocks of scan data of the type produced by a reader having a 2D image sensor, together with a pointer or tracking memory MP suitable for use in storing address or pointer information for identifying the memory spaces to be used for entering new scan data, decoding, etc. Since the amount of scan data in each block of scan data is known in advance, being the same for each scan, the starting and ending addresses for each memory space (e.g., A_1 and B_1 and A_N and B_N, etc.) will also be the same for each scan. As a result, the memory to be used for storing new scan data, decoding etc. may be specified by specifying just a few bits stored in memory MP. Location CS, for example, may be used as a pointer which identifies the memory where the current scan is being stored, and location NS may be used as a pointer which identifies where the next scanned image is to be stored.

Similarly, location CD may be used as a pointer which identifies the memory space where the current decode is being undertaken. Finally, location ND may be used as a pointer which identifies where the next available image is for decoding purposes.

Under ordinary circumstances, three scan data memory spaces will be sufficient to keep the decoding activity of the reader fully occupied and current. This is because the tracking method allows the skipping over of old blocks of scan data as necessary for the decoder to remain occupied and current. If the decoding load becomes extremely heavy, however, it is possible that more old blocks of scan data are skipped over than is advisable. In such instances, it may be desirable to increase the number of memory spaces from 3 to N, where N may be 4 or even more, and to use more than one decoding circuit. If such an increased number of memories and decoders are used, blocks of scan data may be distributed among the memories according to a simple sequential rule and kept track of by increasing the number of bits in the pointers of memory space MP. In addition, the decoding circuits may be assigned to the then most current complete block of scan data as they become free. It will be understood that all such numbers of memory spaces and decoding circuits and the associated tracking procedure are within the contemplation.

Referring to FIG. **15**, there is shown a simplified version of FIG. **6**A which eliminates those blocks which do not relate directly to the use of the scanning-decoding parameters of FIG. **7**B to produce decoded output data. Of the blocks shown in FIG. **15**, blocks **625**, **627**, and **646** are common to prior art readers and to readers constructed. The

remaining blocks of FIG. **15** operate either singly or in various combinations to establish the permitted combinations of the scanning-decoding modes shown in FIG. **7**B. These remaining blocks together comprise the preferred embodiment of the means by which the reader is controlled in accordance with the scanning-decoding relationships called for by the parameter table thereof. Other combinations of flow chart blocks, and other combinations of scanning-decoding parameters may also be used. Blocks **642** and **643** may, for example, be configured so that only a preset number of multiple symbols or a preset number of repeats is permitted. Alternatively, all scanning-decoding control blocks may be collectively replaced by a look-up table which directly specifies the next action to be taken. These and other variants will be understood to be within contemplation.

In view of the foregoing, it will be seen that the scanning and decoding processes may have a selectable one of any of a plurality of different relationships with one another, some of these relationships being tracking relationships and some being non-tracking relationships. The menuing feature allows a user to select that operating mode, whether or not tracking, which gives the best overall data throughput rate in view of the user's then current objectives.

(b) Autodiscrimination/Code Options

The manner in which the code options called for by the parameter table are implemented in conjunction with the autodiscrimination feature, will now be described with reference to the flow charts of FIGS. **16** and **18**. Generally speaking, the flow chart of FIG. **16** illustrates the 1D portion of a complete 1D/2D autodiscrimination process, while the flow chart of FIG. **18** illustrates the 2D portion of a complete 1D/2D autodiscrimination process. If both the 1D and 2D code options of the parameter table are enabled (see options B**1** and B**2** of FIG. **7**B), the steps called for by both FIGS. **16** and **18** will be executed before the autodiscrimination process is completed. If, however, only one or the other of the 1D and 2D code options of the parameter table is enabled, only the steps called for by FIG. **16** or by FIG. **18** will be executed before the autodiscrimination process is completed. It will therefore be seen that the menuing features and the autodiscrimination features of the present reader interact with one another in a manner that allows a user to tailor the autodiscrimination circuitry as necessary to achieve the highest possible data throughput rate for a particular application.

In order to gain an understanding as a whole, it should be borne in mind that the above-described relationships between the decoding and menuing processes exist as a subset of an even more complex set of relationships that include the tracking and multiple symbols features. When, for example, a portion of the flow chart of FIGS. **16** and **18** calls for an attempted decode, it must be remembered that the attempted decode takes place in the context of the tracking or non-tracking relationships indicated by the parameter table options. In addition, the number of passes that the processor makes through the flow chart of FIG. **16**, before continuing on to the flow chart of FIG. **18**, depends upon whether or not the multiple symbols feature has been enabled.

In principle, at least, each one of the possible combinations of the above-described options may be represented in a complete and separate flow chart and described as such. Because adopting the latter approach would obscure rather than clarify, however, the present application will describe these combinations simultaneously in terms of a representative flow chart, with different options being described potential variants of that representative flow chart.

Turning first to the flow chart of FIG. **16**, there is shown the 1D portion of the autodiscrimination process, which operates on a set of image data that has been scanned from a target symbol of unknown type and orientation and stored in RAM **45**. If the reader is a 2D reader, this image data will comprise a gray scale representation of the 2D image formed on the image sensor, each pixel of the image sensor being represented by an image data element that includes an 8 bit gray scale indication of its brightness. If, on the other hand, the reader is a 1D reader, the image data may comprise either binary or gray scale values.

If the reader includes a 2D image sensor, this image data will have been scanned as a 2D image while the reader is held substantially stationary with respect to its target. If the reader includes a 1D image sensor this image data will have been scanned as a series of 1D images while the reader is being moved asynchronously across the target in the manner described in copending commonly assigned U.S. patent application No. 08/504,643, now U.S. Pat. No. 5,773,806, which is expressly incorporated herein by reference.

On encountering block **1605**, the processor is directed to calculate the "activities" of selected image data elements. The "activity" of a point P as used herein comprises a measure of the rate of change of the image data over a small two dimensional portion of the region surrounding point P. This activity is preferably calculated along any two arbitrarily selected directions which are mutually perpendicular to one another, as shown by the lines parallel to directions X and Y of FIG. **17**A. One example of an activity calculation is that which is based on the squares of the gray scale differences of two pairs of points P**1**X–P**2**X and P**1**Y–P**2**Y that are centered on point P, as shown in FIG. **17**A. Two mutually perpendicular directions are used because the orientation of the symbol is unknown and because a high activity level that by chance is difficult to detect in a first direction will be readily detectable in a second direction perpendicular to that first direction.

In the preferred embodiment, an activity profile of the image data is constructed on the basis of only a selected, relatively small number of image data elements that are distributed across the field of view that corresponds to the stored image data. Using a relatively small number of data elements is desirable to increase the speed at which the symbol may be imaged. These selected points may be selected as the points which lie at the intersections of an X-Y sampling grid such as that shown in FIG. **17**A. The spacing of the lines defining this grid is not critical, but does affect the resolution with which the activity profile of the image can be measured.

When the processor has determined the activities of the selected image data points, it is directed to block **1610**, which causes it to look for candidate bar code symbols by identifying regions of high activity. This is conveniently done by determining which sets of image data points have activities that exceed a predetermined activity threshold value. A simplified, one-dimensional representation of this step is illustrated in FIG. **17**B, wherein those image data points having an activity that exceed a threshold value TH are labeled as a candidate symbol region CSR**1**.

In embodiments which are adapted to find and decode all of the symbols that occur in fields of view that include a plurality of bar code symbols, (i.e., embodiments in which the multiple symbols option is enabled), the result of the step called for by block **1610** is the identification of a plurality of candidate symbol regions (CSRs), any one or more of which may be a bar code symbol. Whether or not they are bar code symbols is determined on the basis of whether they are

decodable. As will be explained more fully later, if the multiple symbols option is not enabled, the processor may be instructed to select one of the CSRs according to a suitable selection rule, such as the largest CSR first, the CSR nearest the center of the field of view first, the CSR with the highest total activity first, etc., and then attempt to decode only that symbol and stop, whether or not a symbol has been decoded. Alternatively, as a further option, the processor may be instructed to attempt to decode each CSR in turn until one of them is successfully decoded, and then stop. If the multiple symbols option is enabled, the processor will process all of the CSRs, in turn, according to a suitable priority rule, and continue to do so until all of the CSRs have been either decoded or have been determined to be undecodable.

Once all CSRs have been located, the processor is directed to block **1615**, which calls for it to select the then largest (or most centrally located) as yet unexamined CSR for further processing, and then proceed to block **1620**. The latter block then causes the processor to find the centroid or center of gravity of that CSR, before proceeding to block **1625**. An example of such a centroid is labeled C in FIG. **17**C. Because the steps involved in finding a centroid are well known, they will not be described in detail herein.

On encountering block **1625**, the processor is directed to examine the selected CSR by defining various exploratory scan lines therethrough, determining the activity profile of the CSR along those scan lines, and selecting the scan line having the highest total activity. In the case of a 1D bar code symbol, this will be the direction most nearly perpendicular to the direction of the bars, i.e., the optimum reading direction for a 1D symbol.

On exiting block **1625**, the processor encounters blocks **1630** and **1635**. The first of these sets a scan line counter to zero; the second defines an initial, working scan line through the centroid in the previously determined direction of highest activity. The result of this operation is the definition, in the image data space representation of the CSR, of a working scan line such as SC=0 in FIG. **17**C.

Once the initial scan line has been defined, the processor is directed by block **1640** to calculate, by interpolation from the image data of the CSR, the values of sampling points that lie along this scan line. This means that, for each sampling point on the initial scan line, the processor will calculate what brightness the sampling point would have if its brightness were calculated on the basis of the weighted brightness contributions of the four nearest measured image data points of the CSR. These contributions are illustrated by the dotted lines which join the sample point SP of FIG. **17**D to the four nearest image data points DPA–DPD. So long as these sampling points are more closely spaced than the image data points, this interpolation procedure will be performed on a subpixel basis, and will produce a usably accurate representation of the image data along the scan line. The result of the subpixel interpolation of the sampling points on a representative scan line of this type is shown in FIG. **17**E. Because the particulars of the subpixel interpolation process are known to those skilled in the art, this process will not be further described herein.

Once the above-described scan line data have been calculated, the processor is directed to block **1645**, which calls for it to binarize the scan line data, i.e., convert it to a two-state representation of the data which can be processed as a candidate for 1D decoding. One such representation is commonly known as a timercount representation. One particularly advantageous procedure for accomplishing this binarization process is disclosed in U.S. Pat. No. 5,286,960, which is hereby incorporated herein by reference.

On exiting block **1645**, the processor will be in possession of a potentially decodable two-state 1D representation of the CSR. It then attempts to decode this representation, as called for by block **1650**. This attempted decoding will comprise the trial application to the representation of one 1D decoding program after another until the latter is either decoded or determined to be undecodable. Because decoding procedures of the latter type are known to those skilled in the art, they will not be discussed in detail herein.

As the 1D autodiscrimination process is completed, the processor is directed to decision block **1655** which causes it to continue along one of two different paths, depending on whether or not decoding was successful. If it was not successful, the processor will be caused to loop back to block **1635**, via blocks **1660** and **1665**, where it will be caused to generate a new working scan line that is parallel to initial scan line SC=0, but that passes above or below centroid C. This looping back step may be repeated many times, depending on the "spacing" of the new scan lines, until the entire CSR has been examined for decodable 1D data. If the entire CSR has been scanned and there has been no successful decode, the processor is directed to exit the just-described loop via block **1670**. As used herein, the term "parallel" is used in its broad sense to refer to scan lines or paths which are similarly distorted (e.g., curvilinear) as a result of foreshortening effects or as a result of being imaged from a non-planar surface. Since compensating for such distorting effects is known, as indicated, for example, by U.S. Pat. No. 5,396,054, it will not be discussed in detail herein.

Block **1670** serves to direct the processor back to block **1615** to repeat the above-described selection, scanning and binarizing steps for the next unexamined CSR, if one is present. If another CSR is not present, or if the processor's program calls for an attempt to decode only one CSR, block **1670** causes the processor to exit the flow chart of FIG. **16** to begin an attempt to decode the then current set of image data as a 2D symbol, in accordance with the flow chart of FIG. **18**. If other CSRs are present, and the multiple symbols option is enabled, block **1670** directs the processor back to block **1615** to repeat the selection, scanning and binarizing process for the next CSR, and the next, and so on, until there is either a successful decode (block **1655**) or all of the CSRs have been examined (block **1670**).

If the processing of the first CSR has resulted in a successful decode, block **1655** directs the processor to block **1675**, which causes it to determine whether the decoded data indicates that the CSR contains a 1D stacked symbol, such as a PDF417 symbol. One example of such a symbol is shown in FIG. **19**D. If it is not, i.e., if the decoded symbol includes only a single row of bars, the 1D data is stored for later outputting in accordance with block **648** of the main program of FIG. **6**A, as called for by block **1680**. Alternatively, the data may be output immediately and block **648** later skipped over. Then, if there are no remaining unexamined CSRS, or if the multiple symbols option is not enabled, the processor is directed to exit the flow chart of FIG. **16** via block **1682**. If, however, there are remaining CSRs and the multiple symbols option is enabled, block **1682** will direct the processor back to block **1615** to begin processing the next CSR, and the next, and so on until all CSRs have been examined and decoded (block **1682**) or examined and found to be undecodable (block **1670**).

If, on encountering block **1675**, the decoded data indicates that the CSR contains a 1D stacked symbol, the above-described processing is modified by providing for the repetition of the scanning-digitizing process, beginning with

block **1635**. This is accomplished by blocks **1684**, **1686** and **1688** in a manner that will be apparent to those skilled in the art. Significantly, by beginning the repeating of the process at block **1635**, all additional scan lines defined via the latter path will be parallel to the first decodable scan line, as required by a 1D stacked symbol, at least in the broad sense discussed earlier.

In view of the foregoing, it will be seen that, depending on the number of CSRs that have been found in the stored image data, and on the enablement of the multiple symbols option, the flow chart of the embodiment shown in FIG. **16** will cause all 1D symbols in the image data to be either decoded or found to be undecodable before directing the processor to exit the same.

As will be explained more fully in connection with FIG. **20**, the 2D autodiscrimination flow chart of FIG. **18** may be processed after the processing of the 1D autodiscrimination flow chart of FIG. **16** has been completed. It may also be processed without the flow chart of FIG. **16** having been previously processed, i.e., the 1D portion of the 1D/2D autodiscrimination process may be skipped or bypassed. (In principle, the steps of the 2D portion of the 1D/2D autodiscrimination process (FIG. **18**) may also be processed before the 1D portion thereof (FIG. **16**), although this option does not comprise the preferred embodiment). This is because the code options of the menuing feature make all of these options selectable by the user. It will therefore be understood that the present feature contemplates all possible combinations of autodiscrimination options.

Referring to FIG. **18**, there is shown a flow chart of the 2D portion of the 1D/2D autodiscrimination process. When the flow chart of FIG. **18** is entered, the image data that is stored in RAM **45** is the same as that which would be stored therein if the flow chart of FIG. **16** were being entered. If the reader is a 2D reader this image data will comprise an array of 8-bit gray scale image data elements produced by image sensor **32-2** and its associated signal processing and A/D converter circuits **3502** and **36-2**. If the reader is a 1D reader that produces a 2D image by being moved across the target symbol, the image data will comprise an array of binary data elements such as those shown in above-cited copending application No. 08/504,643, now U.S. Pat. No. 5,773,806.

The flow chart of FIG. **18** begins with a block **1805**, which directs the processor to convert the gray scale image data representation stored in RAM **45** (if present) into a two-state or binarized representation of the same data. This may be accomplished in generally the same manner described earlier in connection with FIG. **17**B, i.e., by comparing these gray scale values to a threshold value and categorizing these values as is or 0s, depending upon whether they exceed or do not exceed that threshold value.

Once the image data has been binarized, the processor continues on to block **1810**, which causes it to identify and locate all of the 2D finder patterns that appear in the field of view of the image data. This is preferably accomplished by examining all of the candidate 2D finder patterns (CFPs) that are present and identifying them by type, i.e., identifying whether they are bullseye type finder patterns, waistband type finder patterns or peripheral type finder patterns. An example of a bullseye type finder pattern is shown in the central portion of the 2D bar code symbol of FIG. **19**A, which symbol encodes data in accordance with a 2D matrix symbology named "Aztec." An example of a waistband type finder pattern is shown in the middle portion of the 2D bar code symbol of FIG. **19**B, which symbol encodes data in accordance with a 2D matrix symbology named "Code One". An example of a peripheral type finder pattern is shown in the left and lower edges of the 2D bar code symbol of FIG. **19**C, which symbol encodes data in accordance with a 2D matrix symbology known as "Data Matrix." The finder identification process is performed by applying to each CFP, in turn, a series of finder pattern finding algorithms of the type associated with each of the major types of finder patterns. Since such finder finding algorithms are known for finders of the waistband and peripheral types, these algorithms will not be discussed in detail herein. One example of a finder finding algorithm for a waistband type finder, may be found, for example, in "Uniform Symbology Specification Code One", published by AIM/USA Technology Group. Finder finding algorithms for bullseye type finders that include concentric rings, (e.g. MaxiCode) are also known and will also not be described in detail herein.

Particularly advantageous for purposes, however, is bullseye type finder finding algorithm of the type that may be used both with 2D symbologies, such as MaxiCode, that have bullseye finder patterns that include concentric rings and with 2D symbologies, such as Aztec, that have bullseye finder patterns that include concentric polygons. A finder finding algorithm of the latter type is described in copending, commonly assigned U.S. patent application No. 08/504,643, now U.S. Pat. No. 08/441,446, which has been incorporated herein by reference. The Aztec 2D bar code symbology itself is fully described in U.S. patent application No. 08/441,446, which has also been incorporated herein by reference.

Once all of the finder patterns have been located and their types have been determined, the processor is directed to decision block **1815**. This block affords the processor an opportunity to exit the flow chart of FIG. **18**, via exit block **1820**, if no 2D finder patterns could be found and typed. This block speeds up the execution of the program by skipping over decoding operations which have no hope of success without their associated finder pattern.

If a finder pattern has been found and typed, the processor is directed to block **1825**. This block causes the processor to select for decoding the bar code symbol whose finder is closest to the center of the field of view of the image data. Optionally, the processor may be instructed to find the largest 2D bar code symbol that uses a particular 2D symbology or the 2D bar code symbol using a particular 2D symbology which is closest to the center of the field of view of the image data. The "closest-to-the-center" option is ordinarily preferred since a centrally located symbol is likely to be a symbol, such as a menu symbol, at which the user is deliberately aiming the reader. Once this selection has been made, the processor attempts to decode that symbol, as called for by block **1830**. If this decoding attempt is successful, as determined by decision block **1835**, the resulting data may be stored for outputting in accordance with block **648** of the main program of FIG. **6**A, as called for by block **1840**. Alternatively, the decoded data may be output immediately and block **648** later skipped over. If the decoding attempt is not successful, however, block **1840** is skipped, and the processor is directed to decision block **1845**.

If the user has elected not to use the multiple symbols option, block **1845** may direct the processor to exit the flow chart of FIG. **18**, via block **1850**, after any 2D symbol has been successfully decoded. Optionally, block **1845** may be arranged to direct the processor to exit the flow chart of FIG. **18** after the attempted decoding of the centermost symbol, without regard to whether or not the decoding attempt was successful.

If the user has elected to use the multiple symbols option, block **1845** will direct the processor back to block **1825** to

process the next 2D symbol, i.e., the symbol whose CFR is next closest to the center of the field of view. The above-described attempted decoding and storing (or outputting) steps will then be repeated, one CFR after another, until there are no more symbols which have usable finder patterns. Finally, when all symbols having usable finder patterns have been either decoded or found to be undecodable, the processor will exit the flow chart of FIG. **18**, via block **1850**, to return to the main program of FIG. **6**A.

In view of the foregoing, it will be seen that, depending on the number of identifiable CFRs that have been found in the stored, digitized image, and on the enablement of the multiple symbols option, the 2D autodiscrimination routine shown in FIG. **18**, will cause one or more 2D symbols in the image data to be either decoded or found to be undecodable before directing the processor to exit the same.

For the sake of clarity, the foregoing descriptions of the 1D and 2D phases of the 1D/2D autodiscrimination process have been described separately, without discussing the combined or overall effect of the code options and scanning-decoding options discussed earlier in connection with FIG. **7**B. The overall effect of these code options and the manner in which they are implemented will now be described in connection with FIG. **20**. As will be explained presently, FIG. **20** shows (with minor simplifications) the contents of block **627** of FIG. **6**A. It also shows, as blocks **2010** and **2035** (again with minor simplifications), the 1D and 2D autodiscrimination routines discussed earlier in connection with FIGS. **16** and **18**, respectively.

On entering the flow chart of FIG. **20**, the processor encounters a block **2005** which causes it to determine, with reference to the code options of the parameter table, whether all of the 1D codes have been disabled. If they have not, the processor continues to block **2010**. In accordance with block **2010**, the processor performs the 1D autodiscrimination process described in connection with FIG. **16**, using the1D code and scanning-decoding options indicated by the parameter table. Depending upon whether 1D decoding was successful, as determined by block **2015**, the processor either outputs (or stores) data per block **2020** and exits, or continues on to blocks **2030** and **2035** to begin the 2D autodiscrimination process.

If all 1D codes have been disabled, the processor is directed directly to block **230**, thereby skipping block **2010** in its entirety. Then, unless all 2D codes have also been disabled (per block **2030**), it proceeds to block **2035** to begin the autodiscrimination process described in connection with FIG. **18**, using the 2D codes and scanning-decoding options indicated by the parameter table. Depending upon whether 2D decoding was successful, as determined by block **2040**, the processor either outputs (or stores) data, per block **2045**, or returns to the main program of FIG. **6**A. Returning to the latter then causes or does not cause further scans to be made depending on the states of blocks **635** and **640** thereof.

In view of the foregoing, it will be seen that the 1D/2D autodiscrimination process may be practiced in many different ways, depending upon the menuing options that have been chosen by the user. Among these menuing options, the code options increase the data throughput rate of the reader by assuring that the processor does not waste time trying to autodiscriminate and decode symbols which it has been told are not present, or are not of interest. The scan tracking options also increase the data throughput rate of the reader by assuring that the scanning and decoding phases of read operations both operate, to the extent possible in view of the then current decoding load and decoding options, at a 100% utilization rate. Even the multiple symbols option also increases the data throughput rate of the reader by either discontinuing the reading of symbols that are not centered and therefore not of interest or speeding up the processing of multiple symbols that are of interest. Thus, for a processor with a given performance rating and a set of decoding programs of given length, the apparatus assures a higher overall data throughput rate than has heretofore been possible.

There is provided an optical scanning and decoding apparatus and method, suitable for use with bar code readers, bar code scanning engines, and portable data terminals (PDTs), which combines improved scanning-decoding and autodiscrimination features in the context of an apparatus and method which also provides imporved menuing and reprogramming features.

In accordance with the menuing feature, there is provided an improved apparatus and method which enables a user to determine the current operating mode of an optical reading apparatus, and to rapidly and conveniently change that operating mode to optimize it for operation under then current conditions. The menuing feature, for example, enables the user, via a machine readable table of pre-recorded menu symbols, to command the reader to communicate with a host processor using one of a number of protocols, to command the reader to format the decoded output according to host processor requirements, or to command the reader to report to the host processor any of a plurality of types of information about the current operating state of the reader, such as the version of software then being used, the code options that are then being used, and even a complete listing of the reader's parameter table. If a suitable printer is available, the complete status of a first reader may be output as a machine readable menu symbol that other, similarly equipped readers may read and use to reconfigure themselves for operation in the same manner as the first reader.

In accordance with the reprogramming feature, there is provided an improved apparatus and method by which an optical reader may be reprogrammed from a source external to the reading apparatus, with or without the participation of a user. This external source may be either on-site, i.e., located at the same local facility as the reader, or off-site, i.e., located at a remote facility that is coupled to the local facility only via a transmission line or computer network. When actuated, the reprogramming feature enables a reader to reprogram itself, either in whole or in part, and thereby become able to operate with operating software of the latest type. Depending on the application, the reprogramming of the reader may be initiated either by a host processor external to the reader, as by a command issued via the reader's communication port, or by a user initiated command issued as a part of the above-mentioned menuing process.

In accordance with another aspect of the reprogramming feature, a local host processor may be configured to carry out reprogramming of an optical reader or another type of portable data terminal. In a reprogramming subroutine a local host processor can be made, at the selected of a user, to replace an entire main program and parameter table of a reader, or else one of either a main program or a parameter table of an operating program individually.

In accordance with another subprogram of a local host processor, the local host processor can be made to edit a parameter table. When this subprogram is selected the user may either edit the parameter table that is stored in memory device of the reader or else edit a parameter table stored in a memory device in communication with the local host

processor. After editing, the user may write the edited parameter table to the reader's memory device, write the edited parameter to a bulk storage device for later use, or print or dispaly the edited parameter table.

In accordance with another aspect, an optical reader may be made to receive a component control instruction from a host processor which is transmitted in response to a user input command to remotely control an optical reader. In accordance with this aspect, the optical reader is made to execute a component control instruction substantially on-receipt thereof. In one embodiment, execution by an optical reader of a component control instruction has the same effect as a reader trigger being manually pulled.

There is also provided an optical scanning and decoding apparatus and method which includes improved scanning-decoding and autodiscrimination features, either or both of which may be used in conjunction with, and/or under the control of, the above-described menuing and reprogramming features. In other words, the autodiscrimination feature is made available tothe user on a nemu selectable or reprogrammable basis to speed up and/or update the decoding phase of the scanning and decoding process. Together, these features enable the reading apparatus to read and decode a wide range of optically encoded data symbols at an improved data throughput rate.

When a reader is one in which the scan engine cannot be readily started and stopped, or in which such starts and stops impose unacceptable delays or produce user perceptible flicker, preferably operates in one of the tracking relationships described in previously mentioned copending application No. 08/914,883, now U.S. Pat No. 5,942,741. One of these tracking relationships is a Skip Scan tracking relationship in which the results of one or more scans may be skipped over entirely in favor of more recently produced scan results. Another is a Decode On Demand tracking relationship in which decoding is suspended briefly as necessary to allow a scan then in progress to be completed. The latter relationship is ordinarily not prefered, but is still useful when the reader is such that its scan memory is able to store only two complete blocks of scan data.

When the reader is one in which the scan engine can readily be stopped, the present reader may operate in the tracking relationship described in previously mentioned U.S. Pat. No. 5,463,214. With this, "Scan On Demand" tracking relationship, scanning is suspended briefly as necessary to prevent scanning and decoding from becoming uncorrelated with one another.

In the preferred embodiment, the reader includes an algorithm that is able to accommodate any of the above-described scanning-decoding relationships, among others. Which of them is actually used will vary form reader to reader depending upon the size and type of memory and the type of scan engine used thereby, and may be changed from time to time.

The present reader also contemplates and provides for at least one scanning- decoding relationship which does not fall within the meaning of the above-defined tracking relationships. One of these non-tracking relationships is a "One Shot" relationship or mode in which a single scan is followed by a single decoding attempt and then a stoppage. Such scanning-decoding events may be initiated by respective single actuations of a manual trigger. Because of its inherently discontinuous nature, the use of the One Shot mode implies the non-use of any of the above-mentioned tracking modes.

Two other such scanning-decoding relationships are referred to herein as the "Repeat Until Done" relationship or mode and the "Repeat Unitl Stopped" relationship or mode. With the Repeat Until Done relationship, scanning and decoding operations follow one after another until successful decode occurs, and are then dicontinued. With the Repeat Until Stopped relationship, scanning and decoding operations follow one after another and continue, even after sets of decoded data are stored or output, until instructed to stop by the release of the trigger or by the readers' program. Because of their repetitive nature, the use of Repeat Until Done and Repeat Until Stopped modes are usable both in conjunction with the above-described tracking modes and independently of those tracking modes. As a result, the Repeat Until Done and Repeat Unitl Stopped modes may be implemented as user selected non-tracking relationships or as tracking relationships.

In embodiments that use the auto discrimination feature, there is provided a method and apparatus by which a plurality of different symbols of a multiplicity of different types may be scanned and decoded in a manner that is optimized for a particular application, on either a menu selectable or a reprogrammable basis. When all of the symbols to be autodiscriminated are known to be ID symbols, for example, the data throughput rate may be increased by structuring the autodiscrimination feature so that no attempt is made to decode **2**D symbols, or vice versa. When, on the other hand the symbols to be autodiscriminated are known to all be of (or all not to be of) a few types, whether **1**D or **2**D, the data throughput rate may be increased by structuring the autodiscrimination feature so that all but a few (or only a few) **1**D and/or **2**D symbologies are disabled, i.e., so that no attempt is made to decode them. Other possible autodiscrimination options include not decoding or not ouputting data for symbols that encode messages that are too long or too short to be of interest in a particular application. Any of these options may be chosen and changed as necessary to achieve the highest possible data throughput rate.

Because of the large number of different combinations of distinct operational states that are make possible thereby, the apparatus and method will be seen to have a portean quality that not makes it usable in a large number of different application, but also enables it to continue to remain so unable a new functions, new bar code symbologies and new and updated decoding programs are developed in the fuuture.

While the present invention has necessarily been described with reference to a number of specific embodiments, it will be understood that the time spirit and scope of the present invention should be determined only with reference to the following claims.

What is claimed is:

1. An optical reader for scanning and decoding at least one optically encoded symbol, the optical reader comprising:

a program loading component operative to store an externally generated program in the optical reader; and

a program execution component coupled to the program loading component, the program execution component being operative to execute the externally generated program stored in the optical reader to thereby perform a predetermined task in accordance with the externally generated program, whereby executing the externally generated program includes replacing at least a portion of the optical reader program.

2. The optical reader of claim **1**, wherein the program loading component and the program execution component are comprised of a programmable controller.

3. The optical reader of claim **2**, wherein the programmable controller comprises an ASIC.

4. The optical reader of claim **2**, wherein the programmable controller comprises a microprocessor device.

5. The optical reader of claim **1**, further comprising a communications interface coupled to the program loading component and an external device, the communications interface being adapted to transmit the externally generated program to the program loading component by communicating with the external device.

6. The optical reader of claim **5**, wherein the communications interface is adapted to communicate with the external device over a transmission facility that includes at least one copper transmission wire.

7. The optical reader of claim **5**, wherein the communications interface is adapted to communicate with the external device over a transmission facility that includes a wireless device.

8. The optical reader of claim **5**, wherein the communications interface is adapted to communicate with the external device over a transmission facility that includes an RF device.

9. The optical reader of claim **5**, wherein the communications interface is adapted to communicate with the external device over a transmission facility that includes an RS-232 compatible device.

10. The optical reader of claim **5**, wherein the communications interface is adapted to communicate with the external device over a transmission facility that includes a computer networking device.

11. The optical reader of claim **10**, wherein the computer networking device is an Ethernet device.

12. The optical reader of claim **5**, wherein the communications interface is adapted to communicate with the external device over a transmission facility that includes at least one optical fiber.

13. The optical reader of claim **1**, wherein the external device includes a computer.

14. The optical reader of claim **1**, wherein the external device includes a machine readable diskette.

15. The optical reader of claim **1**, wherein the external device includes a CD/ROM.

16. An optical reader for scanning-decoding at least one optically encoded symbol, the optical reader comprising:

a communications interface adapted to communicate with an external device;

an imaging assembly for scanning the at least one optically encoded signal to thereby produce digital imaging data; and

processing means for,

receiving the digital imaging data from the imaging assembly,

decoding the digital imaging data in accordance with an optical reader program stored in an optical reader memory,

loading an externally generated program into the optical reader memory via the communications interface, the externally generated program corresponding to a new task, and

executing the externally generated program to thereby perform the new task, whereby executing the externally generated program includes replacing at least a portion of the optical reader program.

17. The optical reader of claim **16**, wherein the step of executing the externally generated program includes replacing all of the optical reader program.

18. A method for instructing an optical reader to perform a task it is not programmed to perform, the method comprising:

loading an externally generated program into a memory located in the optical reader; and

executing the externally generated program to perform the task, whereby the step of executing the externally generated program includes replacing a portion of the optical reader program.

19. The method of claim **18** wherein the externally generated program comprises a diagnostic application program.

20. The method of claim **18**, wherein the externally generated program includes a reprogramming routine for loading a second externally generated program into the optical reader.

21. The method of claim **20**, wherein the reprogramming routine further comprises;

receiving a line of code of the second externally generated program from an external programming source;

checking the correctness of the line of code; and

storing the correct line of code to an erased portion of EROM located in the optical reader.

22. The method of claim **21**, wherein the correctness of the line of code is checked by performing a checksum operation.

23. The method of claim **21**, wherein external programming source is transmitted a negative acknowledgment if the line of code is incorrect.

24. The method of claim **23**, wherein the step of receiving is repeated if the line of code is incorrect.

25. The method of claim **21**, wherein the steps of receiving, checking, and storing are repeated until the last line of the externally generated application program is stored in EROM.

26. A set of program interfaces tangibly embodied on a computer-readable medium, the program interfaces being executable on a computer in conjunction with a computer program that controls an optical reader, the set of program interfaces comprising:

a first interface that receives a load command, and program code from an externally generated program, the interface returning an acknowledgment indicating whether the externally generated program was successfully loaded; and

a second interface that receives the acknowledgment, the second interface directing the computer to execute the externally generated program in response to the acknowledgment.

27. The set of program interfaces of claim **26**, wherein the load command is an externally generated command.

28. The set of program interfaces of claim **27**, wherein the externally generated command is an interrupt command.

29. The set of program interfaces of claim **26**, wherein the externally generated program is a diagnostic program for testing the optical reader.

30. The set of program interfaces of claim **26**, wherein the externally generated program is a routine for reprogramming the optical reader.

31. The set of program interfaces of claim **30**, wherein the routine further comprises a third interface that receives a computer program code for controlling the optical reader, the third interface returning at least one acknowledgment indicating whether the computer program code for controlling the optical reader was successfully loaded.

32. The set of program interfaces of claim **31**, wherein the third interface returns an error message when the routine for reprogramming the optical printer is unsuccessful.

33. A reprogrammable optical reader system, the optical reader system having a program stored in memory, the system comprising:

a programming source having at least one software program, the at least one software corresponding to a predetermined task;

a transmission facility coupled to the programming source for transmitting the at least one software program; and

an optical reader coupled to the transmission facility, the optical reader being configured to receive and execute the at least one software program to thereby perform the predetermined task, wherein executing the at least one software program includes replacing a portion of the optical reader program.

34. The system of claim **33**, wherein the optical reader further comprises:

a communications interface connected to the transmission facility, the communications interface operative to receive the software program;

a program loading component coupled to the communications interface, the program loading component operative to store the software program in the optical reader; and

a program execution component coupled to the program loading component, the program execution component operative to execute the software program stored in optical reader.

35. The system of claim **33**, wherein the transmission facility includes a computer network.

36. The system of claim **33**, wherein the transmission facility includes a wireless system.

37. The system of claim **33**, wherein the transmission facility includes at least one metallic wire.

38. The system of claim **33**, wherein the transmission facility includes at least one optical fiber.

39. The system of claim **33**, wherein transmission facility includes a public telecommunications network.

40. The system of claim **33**, wherein the programming source includes an external computer.

41. The system of claim **33**, wherein the programming source includes a diskette.

42. The system of claim **33**, wherein the programming source includes a CD/ROM.

43. A method for reprogramming a first optical reader to perform a task performed by a second optical reader, the first optical reader having a first parameter table stored in memory, the second optical reader being programmed to perform the task by a second parameter table resident in the second optical reader, the method comprising:

providing an optically encoded menu symbol corresponding to the second parameter table; and

scanning-decoding the optically encoded menu symbol with the first optical reader to thereby load the parameter table into the first optical reader, wherein the step of scanning-decoding includes replacing at least a portion of the first parameter table.

44. The method of claim **43**, wherein the step of providing further comprises:

providing a host computing system;

downloading the parameter table from the second optical reader to the host computer; and

printing the optically encoded menu symbol.

45. A portable data collection unit configured for communication with an external local host processor spaced apart from said portable data collection unit to which said portable data collection unit transmits data, said portable data collection unit comprising:

(A) a light emitting assembly directing light outwardly from said portable data collection unit;

(B) a two-dimensional solid-state image sensor having pixels;

(C) an optical assembly focusing an image of a target area onto said two-dimensional solid-state image sensor;

(D) an analog-to-digital converter in communication with said two-dimensional solid state image sensor, said analog-to-digital converter configured to convert an analog intensity value of each of a plurality of said pixels into a digital value represented by an N-bit value, where N is an integer greater than 1;

(E) an image frame memory storing two-dimensional electronic images, said image frame memory being in communication with said analog-to-digital converter;

(F) a decoding circuit in communication wit said image frame memory, said decoding circuit decoding bar code symbol representations included in said two-dimensional electronic images stored in said image frame memory;

(G) a portable housing supporting said light emitting assembly, said two-dimensional solid-state image sensor, said optical assembly, said image frame memory, and said decoding circuit;

(H) a display, wherein said portable data collection unit is configured to display message data on said display; and

(I) a radio frequency transceiver facilitating wireless communication between said portable data collection unit and an external host processor spaced apart from said portable data collection unit,

(J) wherein said portable data collection unit is configured to be reprogrammed by any one of (i) receipt of programming data from an external local host processor spaced apart from said portable data collection unit and (ii) receipt of programming data from an external remote off-site processor spaced apart from said portable data collection unit that is communicatively coupled to said portable data collection unit via a computer network.

46. The portable data collection unit of claim **45**, further having a plurality of parameter settings establishing operating characteristics of said portable data collection unit, wherein said portable data collection unit is configured to receive from at least one of said local host processor or said remote host processor parameter setting programming data, and wherein said portable data collection unit is configured to change at least one of said plurality of parameter settings when receiving said parameter setting programming data.

47. The portable data collection unit of claim **46**, wherein said portable data collection unit is configured to receive from at least one of said local host processor or said remote host processor programming data which when received by said portable data collection unit results in said portable data collection unit operating in accordance with one of a new main program or a modified main program.

48. The portable data collection unit of claim **45**, wherein said portable data collection unit is configured to receive from at least one of said local host processor or said remote host processor programming data which when received by said portable data collection unit changes a manner in which said portable data collection unit can be reprogrammed.

49. The portable data collection unit of claim **45**, wherein said portable data collection unit is configured to receive from at least one of said local host processor or said remote host processor programming data provided by a bar code decoding program.

50. The portable data collection unit of claim **45**, wherein said portable data collection unit operates in a mode in which said portable data collection unit receives from said external remote off-site host processor communicatively coupled to said portable data collection unit via a computer network programming data provided by a diagnostic program.

51. The portable data collection unit of claim **45**, wherein said portable data collection unit operates in a mode in

which said portable data collection unit receives from said external remote off-site host processor communicatively coupled to said portable data collection unit via a computer network programming data provided by a diagnostic program, and wherein said portable data collection unit further operates in a mode in which said portable data collection unit receives from said external local host processor parameter setting programming data specifying whether a light source of said light emitting assembly is enabled or disabled.

52. The portable data collection unit of claim **45**, wherein said light emitting assembly includes an aiming light source, and wherein said portable data collection unit is configured to disable said aiming light source on receipt of a user-initiated signal initiated by a user to disable said aiming light source.

53. The portable data collection unit of claim **52**, wherein said portable data collection unit is configured so that said portable data collection unit receives said user-initiated signal that disables said aiming light source by reading of a specially encoded programming bar code symbol that is encoded such that, when said portable data collection unit decodes said specially encoded bar code symbol, said aiming light source is disabled.

54. The portable data collection unit of claim **45**, wherein said portable data collection device is configured to operate in an operating mode in which said portable data collection unit displays on said display a message indicating a version of software presently residing in said data collection unit.

55. The portable data collection unit of claim **45**, wherein said light emitting assembly includes a laser, and wherein said light emitting assembly directs laser light outwardly from said portable data collection unit.

56. The portable data collection unit of claim **55**, wherein light received onto said two-dimensional solid-state image sensor includes said laser light emitted by said light emitting assembly.

57. The portable data collection unit of claim **45**, wherein said portable data collection unit is configured so that a frame rate of said two-dimensional solid state image sensor is adjustable.

58. The portable data collection unit of claim **57**, wherein said portable data collection unit is configured so that said frame rate of said two dimensional solid state image sensor is controlled by a user.

59. The portable data collection unit of claim **57**, wherein said portable data collection unit is configured so that receipt by said portable data collection unit of a certain user-initiated signal results in said frame rate of said two-dimensional solid state image sensor changing from a first value to a second value.

60. The portable data collection unit of claim **59**, wherein said portable data collection unit is configured so that said portable data collection unit receives said certain user-initiated signal that results in said frame rate changing from a first value to a second value when said portable data collection unit reads a specially encoded programming bar code symbol, said specially encoded programming bar code symbol encoded so that a frame rate of said two-dimensional solid state image sensor changes from a first value to a second value when said portable data collection unit reads said specially encoded programming bar code symbol.

61. The portable data collection unit of claim **57**, wherein said certain user-initiated signal is a parameter setting specifying a frame rate of said two- dimensional solid state image sensor.

62. The portable data collection unit of claim **57**, wherein portable data collection unit is configured so that said portable data collection unit receives said certain user-initiated signal resulting in said frame rate change via said radio frequency transceiver.

63. The portable data collection unit of claim **57**, wherein said portable data collection unit is configured so that said portable data collection unit receives said certain user-initiated signal resulting in said frame rate change from an external host processor which is in communication with said portable data collection unit via a communication link that includes a flexible cable.

64. The portable data collection unit of claim **45**, wherein said image sensor is provided on an integrated circuit chip that does not include said analog-to- digital converter.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,104,456 B2 Page 1 of 1
APPLICATION NO. : 09/746192
DATED : September 12, 2006
INVENTOR(S) : James A. Parker et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 3, line 22. delete “In the post,” and replace with--In the past,--.

Signed and Sealed this

Twenty-sixth Day of December, 2006

JON W. DUDAS
Director of the United States Patent and Trademark Office